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Weeds

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Residual Pre-emergence Herbicides in Soybean Production in Iowa[1]

DAVID W. STANIFORTH and CHARLES R. WEBER[2]

THE control of annual weeds in row-planted crops such as soybeans and corn may become a major production problem whenever weather conditions limit the scope and effectiveness of tillage operations. With corn, the use of 2,4–D has greatly minimized this problem, but with soybeans the utilization of herbicides has been limited. Adaptation of herbicides to soybean production depends not only on herbicide performance but also on economic aspects of the problem. Recent studies (6, 7) reported average bean yield reductions of approximately 10 percent from the competition of average annual weed infestations. This emphasizes the importance of effective weed control and indicates some economic limits to the choice of methods to be utilized in practical weed control for soybeans.

Following the initial report of Anderson and Wolf (1) on the use of 2,4–D as a residual pre-emergence treatment for corn, the technique has been tested extensively on soybeans (4, 8). Recent reports (3, 5) have indicated possibilities for post-emergence application of herbicides in soybeans.

The present study is an attempt to assess the potential role of residual pre-emergence herbicides in soybean production. Data were obtained from a number of tests in which herbicides were tested and evaluated in conjunction with good cultivation practices.

MATERIALS AND METHODS

Experiments were conducted in North Central and Central Iowa on Clarion-Webster silt loam soils from 1949 through 1955. Hawkeye soybeans were seeded at 1 bushel per acre in rows 42 inches apart, at a depth of 1 to 1½ inches. When solid seedings were used, rows

[1]Joint contribution from the Iowa Agr. Exp. Sta., Ames, Iowa and the Crops Research Division, A.R.S., U.S.D.A. U.S. Regional Soybean Laboratory publication No. 307. Journal Paper No. 3260, Iowa Agr. Exp. Sta., Ames, Iowa. Project Nos. 1121 and 1179.

[2]Associate Professor of Botany and Plant Pathology and of Farm Crops; and Associate Professor of Farm Crops and Agronomist, Crops Research Division, A.R.S., U.S.D.A., respectively.

were 7 inches apart and planting rate was 2 bushels per acre. Plots consisted of a single row, or with solid seedings, 6 rows, trimmed to 16 feet in length at harvest. Experimental designs were split-plot randomized blocks with 4 replications. A small power sprayer was used to apply herbicides in 40 gallons of water per acre at indicated rates. Applications were made either immediately after planting or a day or two prior to bean emergence.

Infestations consisted of approximately equal numbers of annual grasses and broadleaved weeds, and varied only slightly among the experimental areas utilized in these tests. Major species included *Setaria viridis* L., *S. lutescens* (Weigel) F. T. Hubb., *Polygonum pensylvanicum* L., *Amaranthus retroflexus* L. and a scattering of other annual weeds.

Rainfall data, observations of weed control, weed counts, yields of mature weeds in some tests, crop injury ratings and seed yields of mature beans were obtained. Various cultivation procedures and other data related to methods are given in the presentation of results.

EXPERIMENTAL RESULTS

Herbicide Testing. A large number of experimental and commercial herbicides were tested on row-planted beans over a range of environmental conditions and weed infestations. In addition to the usual biometric techniques used in soybean yield trials, the following procedures were followed in all herbicide testing experiments: (1) Split-plot designs were used, in which herbicides and dates of application were main plots, and rates of application were sub-plots. Check plots were included as rates in sub-plots. (2) Check plots were cultivated beginning 2 weeks after planting; infestations which survived cultivation approximated those of reasonably clean bean fields. (3) Herbicide-treated plots were cultivated beginning about 25 days after seeding; thus, herbicides were substituted for one early cultivation. (4) All cultivation was done with tractor-mounted shovel equipment.

Data from tests in which effective herbicide treatments were substituted for one early cultivation are summarized in Table 1. These data were selected for presentation since they reflected the results obtained with residual pre-emergence herbicides under weather conditions conducive to optimum herbicide performance. These conditions included the occurrence of moderate rainfall during the interval between herbicide application and bean emergence, the absence of excessive rainfall during this period, the existence of soil temperatures and soil moisture levels most conducive to rapid germination of beans and weeds, and the presence of severe weed infestations in the experimental areas.

Isopropyl and butyl ester formulations of 2,4–dichlorophenoxyacetic acid (2,4–D) gave very good control of annual weeds, including grasses, at rates of 1 and 2 lb/A, but on the average did not give appreciably better weed control or bean yield than that obtained from cultivated checks. Weed control and resultant bean yields following applications of isopropyl N-(3–chlorophenyl)carbamate

Table 1. Yields of soybeans from various rates of application of four herbicides, 1951–54.

Year and test	Time of application[a]	Soybean yields in bu/A[b]												
		2,4-D-lb/A			CIPC-lb/A			DNBP-lb/A				NPA-lb/A		
		0	1	2	0	4	8	0	4	8	12	0	4	8
1951(1)	1	25.5	26.5	26.7	—	—	—	—	—	—	—	—	—	—
	2	24.2	25.4	23.4	—	—	—	—	—	—	—	—	—	—
1951(2)	2	29.8	30.8	27.8	—	—	—	—	—	—	—	—	—	—
1952(1)	1	24.7	21.0	22.2	25.7	27.8	22.4	24.8	23.0	26.4	—	—	—	—
	2	26.2	25.0	25.3	24.5	23.9	22.5	27.2	27.1	26.3	—	—	—	—
1952(2)	1	36.9	36.3	36.4	36.6	38.0	39.8	37.5	37.9	36.1	—	—	—	—
	2	—	—	—	38.6	36.0	37.8	—	—	—	—	—	—	—
1953	1	—	—	—	34.9	33.6	31.4	30.8	—	34.0	29.2	30.7	29.3	26.8
	2	—	—	—	32.7	29.1	30.0	—	—	—	—	—	—	—
1954	1	—	—	—	33.9	34.4	33.6	34.4	—	32.9	32.3	34.6	34.8	33.2
Means		27.9	27.5	27.0	32.4	31.8	30.9					32.6	32.0	30.0
Means for DNBP, 1952								29.8	29.3	29.6				
1953 & 1954								32.6		33.4	30.8			

[a]1—herbicide applied immediately after planting.
2—herbicide applied just prior to bean emergence.

[b]Differences among treatments in these tests were not significant at the 5% level of probability. Coefficients of variation for the several experiments ranged from 6 to 11 percent.

(CIPC), amine salt of 4,6–dinitro ortho secondary butylphenol (DNBP), and sodium salt of N–1–naphthyl phthalamic acid (NPA) were similar in general to those obtained with 2,4–D ester formulations. Four lb/A of CIPC gave almost as good weed control as 8 pounds, while 8 pounds caused some early stunting of bean plants. DNBP at 8 lb/A gave good weed control under most conditions, while 12 lb/A caused crop injury in a few tests. NPA at 4 lb/A gave excellent weed control with little or no bean injury except under very wet conditions after application; 8 lb/A were not necessary for adequate weed control. In general, these four herbicides gave good control of annual weeds under optimum weather conditions, but when the herbicide treatment was substituted for one early shovel cultivation, average bean yields were no different than those obtained with good cultivation and no herbicide application.

Numerous other chemicals were evaluated during the same testing period. The detailed results of portions of three such tests are presented in Table 2, and a general summary of the larger number of tests is contained in Table 3. The data in Table 2 were included to show the type of weed control evaluations made and the various check plots used in these studies. Weed control ratings were made approximately 3 weeks after treatment, and were based on visual observation, recorded on a numerical scale from 1 to 5. A rating of 1 represented almost perfect weed control and a rating of 2 or less was considered adequate weed control. Ratings of 3 or higher indicated poor or no control of weeds. The high ratings reported for the check plots were obtained from uncultivated border rows, and were included to indicate the severity of infestations initially present in the check plots. They do not reflect the degree of weed control obtained with cultivation. Mature weeds were not harvested in all tests due to the pressure of other work. The three tests included in Table 2 sampled a range of rainfall conditions during the interval from bean seeding to emergence.

The amine salt and micronized acid formulations of 2,4–D were effective residual pre-emergence herbicides but were not superior to 2,4–D butyl ester, and they were slightly more subject to leaching by heavy rainfall. This is not evident from the data in Table 2, but was observed in laboratory tests and in other field evaluations of 2,4–D formulations on soybeans and corn. Experience with 2,4–dichlorophenoxyethyl sulfate (Sesone) showed that it was not as effective as 2,4–D esters at comparable rates of residual pre-emergence applications and that it was more easily leached by rainfall. Although excellent control of annual weeds was obtained in some tests with 4 lb/A of Sesone applied shortly after bean emergence, this result was not observed consistently, particularly when weeds had begun to emerge at the time of application. Sodium pentachlorophenate at 15 and 30 lb/A gave good weed control with no bean injury.

In additional experiments, not presently available for publication[3]

[3]Weber, C. R., Lovely, W. G. and Staniforth, D. W. Progress report on rotary hoe for weed control in soybeans. Unpublished data. January 1957.

Table 2. Yields of soybeans, yields of mature weeds and weed control ratings for various rates of pre-emergence application of six herbicides, 1950, 1952 and 1953.

Herbicide	Rate of application lb/A	1950 Ames			1952 Kanawha			1953 Kanawha	
		Beans bu/A	Weeds lb/A	Weed control rating	Beans bu/A	Weeds lb/A	Weed control rating	Beans bu/A	Weed control rating
2,4-D butyl ester	0 (weed-free check)	—	—	—	26.7	0	3.5	—	—
	0 (cult. check)	25.0	483	3.2	24.7	420	3.6	35.9	4.0
	1	22.7*	809	1.2	21.0*	1027	1.8	29.9*	1.0
	2	21.7*	59	1.0	22.2	508	0.8	24.6*	1.0
DNBP	0 (weed-free check)	—	—	—	26.4	0	5.0	—	—
	0 (cult. check)	23.8	157	3.5	24.8	261	4.5	30.8	3.5
	4	23.9	80	1.2	23.0	619	4.0	—	—
	8	23.7	159	1.0	26.4	497	3.3	34.0*	1.0
CIPC	0 (weed-free check)	—	—	—	26.9	0	3.4	—	—
	0 (cult. check)	—	—	—	25.7	608	3.3	34.9	4.0
	4	—	—	—	27.8	508	1.3	33.6	1.5
	8	—	—	—	22.4*	438	1.1	31.4*	1.0
NPA	0 (cult. check)	—	—	—	—	—	—	30.7	3.0
	4	—	—	—	—	—	—	29.3	2.0
	8	—	—	—	—	—	—	26.8*	1.5
2,4-D amine salt	0 (cult. check)	27.7	278	2.5	—	—	—	—	—
	1	24.4*	239	1.2	—	—	—	—	—
	2	22.0*	121	1.0	—	—	—	—	—
2,4-D, micronized acid	0 (cult. check)	25.5	640	3.4	—	—	—	—	—
	1	23.9	312	1.5	—	—	—	—	—
	2	21.6*	237	1.0	—	—	—	—	—
Rainfall distribution and amount during the interval between herbicide application and bean emergence.		2.5 inches, one day after application of herbicides			Only trace amounts			1 inch of rain on the day of bean emergence	

*Differs from cultivated check at 5% level of probability.

Table 3. General results from tests of herbicides which did not prove effective for weed control in soybeans, 1949–1954.

Herbicide	No. of tests	Application	Rate of application in lb/A	Remarks
Triethylamine salt of 2,4-D	7	Residual pre-emergence	1, 2	Not superior to 2,4-D esters as herbicides and more easily leached than ester formulations.
Micronized 2,4-D acid	4	Residual pre-emergence	1, 2	
Acetanalide and acetamide of 2,4-D	6	Residual pre-emergence	1, 2, 3	Slightly less subject to leaching than 2,4-D ester, but only about half as effective as herbicides.
2,4-Dichlorophenoxyethyl sulfate (sesone)	12	Residual pre-emergence	1, 2, 4, 8	No better herbicide than 2,4-D ester and much more subject to leaching by moderate or heavy rain.
Sesone	12	Early post-emergence	1, 2, 4, 8	Caused no bean injury but was practically ineffective as an herbicide except at 8 lb. rate and was not consistent then.
Chloro-methyl-phenylcarbamate	2	Residual pre-emergence	2, 4, 8	Ineffective as an herbicide
Sodium pentachlorophenate	3	Residual pre-emergence	15, 30	Good weed control and no bean injury

2–chloro–N,N–diallylacetamide (CDAA) and NPA were evaluated as residual pre-emergence applications in conjunction with rotary hoe and other cultural practices. CDAA was generally effective for the control of annual grasses and NPA was effective on a number of annual weeds. Effective as these two herbicides were, the degree of weed control obtained was not appreciably better than that obtained with a good cultivation program.

Evaluation of Herbicides in Combination with Shallow Cultivation. The potential role of herbicides was investigated further in conjunction with shallow and shovel cultivations in both row-planted and solid-seeded beans. The butyl ester of 2,4–D and the amine salt of DNBP were utilized in residual pre-emergence applications under weather conditions conducive to optimum herbicide performance. While neither 2,4–D nor DNBP have been widely recommended for use in soybeans, these herbicides gave good weed control under the conditions encountered in the tests reported in Table 4. Shallow cultivations with a spike-tooth harrow were done shortly after bean emergence and one again as weather permitted, but always within 2 weeks after bean emergence. Shovel cultivations in row-planted beans were done carefully to insure maximum weed control under existing weather conditions. The results from experiments with row-planted beans are contained in Table 4.

Extremely wet weather about 10 days after bean emergence in 1951 delayed and impaired the effectiveness of shovel cultivations in row-planted beans. Under these conditions, early post-emergence harrowing materially improved weed control and resulted in an increased bean yield where no herbicides were applied. Residual pre-emergence treatments with 1.5 pounds of 2,4–D ester per acre effectively controlled annual weeds and resulted in significant bean yield increases. Harrowing did not improve appreciably the weed control obtained with the herbicide treatment. In 1952, weather conditions were ideal for shovel cultivations and excellent weed control was obtained with this method. Under this condition, neither harrowing, herbicide application nor the combination of the two materially improved weed control or bean yields.

Data from experiments with solid-seeded beans are summarized in Table 4. These experiments revealed a pattern of results similar to those obtained with row plantings. Early post-emergence harrowing was, in general, the most effective method of controlling annual weeds. Increased bean yields followed its use in all tests except the second test in 1952 where weed infestations were very light. In the first test in 1952, residual pre-emergence treatment with 2,4–D ester adequately controlled annual weeds, but also produced some stunting of beans which was reflected in no increase in bean yield following its use. In 1953, the DNBP residual pre-emergence treatment was superior to harrowing and its effectiveness was not improved by the use of the harrow; residual pre-emergence treatment with 2,4–D ester was equal to harrowing, while the two together were superior. Weed infestations in 1954 were relatively heavy and under these conditions harrowing greatly reduced weed populations and resulted

Table 4. Seed yields of soybeans and yields of mature weeds from experiments with herbicides and cultivation, 1951–1954.

Pre-emergence treatment	Shallow cultivation	Soybean yield in bu/A							Weed yield in lb/A			
		Beans in rows			Beans solid-seeded				Beans in rows		Beans solid seeded	
		1951	1952(1)	1952(2)	1952(1)	1952(2)	1953	1954	1951	1952(1)	1952(1)	1954
None (check)	Harrow	32.4	30.8	38.2	34.0	40.1	25.9	52.2	556	37	250	373
2,4-D ester, 1½ lb/A	Harrow	35.1	30.1	38.1	33.5	41.5	30.9*	—	292	44	192	—
DNBP, 10 lb/A	Harrow	—	—	36.8	—	44.9	28.7	51.0	—	—	—	594
Mean	Harrow	33.8	30.4	37.7	33.8	42.2	28.5	51.6	—	—	—	—
None (check)	None	28.0*	30.0	36.6	26.7*	40.3	22.2*	39.4*	2091	88	843	862
2,4-D ester, 1½ lb/A	None	34.2	29.5	37.8	26.0*	42.2	25.8	—	681	77	910	—
DNBP, 10 lb/A	None	—	—	38.5	—	36.2*	28.7*	38.7*	—	—	—	882
Mean	None	31.1	29.8	37.6	26.4**	39.9	25.6**	39.0**	—	—	—	—

*Differs from harrowed check at 5% level of probability.
**Differs from mean of all harrowed plots at 5% level of probability.

in marked bean yield increases. Pre-emergence application of 10 pounds of DNBP gave only fair weed control and was much less effective than the harrow.

DISCUSSION

The foregoing results demonstrate some advantages and limitations which may attend the utilization of herbicides in soybean weed control. Successful adaptation of herbicide technology to soybean production requires careful screening and testing of potential herbicides, evaluation of the more promising ones under production conditions, and equally important, recognition of the economic aspects of weed control, including some estimate of bean yield reductions resulting from weed competition.

Under Iowa conditions the average bean yield reduction due to nominal infestations of annual weeds was 3 or 4 bushels per acre or about 10% (6, 7). While this figure may vary with weed species, severity of infestations and with seasonal conditions, it remains a reliable estimate of bean losses due to residual infestations in Iowa. These yield reductions emphasize the importance of good weed control practices and at the same time indicate some economic limits which may govern the choice of methods to be utilized in practical weed control for soybeans.

The techniques of herbicide testing and evaluation employed in this study have placed special emphasis on the utilization of residual pre-emergence herbicides as substitutes for part of the cultivation program and as supplements to sound, established cultivation practices. The more effective herbicides utilized in this study included 2,4–D, NPA, DNBP and CDAA. None of these materials controlled weeds well enough to be utilized as substitutes for all the cultivation operations. When they were substituted for the earliest cultivation in row-planted beans they did not materially reduce weed infestations as compared with cultivation, except when wet weather impaired the effectiveness of early cultivation operations. Increased bean yields were not obtained consistently following superior weed control with herbicides in wet weather, possibly the result of slight injury to soybeans from the herbicide treatment. When residual pre-emergence herbicides were used as supplements to cultivation in both row-planted and solid-seeded beans, weed control was improved appreciably in less than half of the tests and only in one test was the increase in bean yield large enough to cover the cost of the herbicide application.

Residual pre-emergence applications of herbicides may provide excellent insurance against delays in early cultivation occasioned by wet weather, particularly since such herbicides function best when rainfall follows application (2). The insurance value of herbicides is lessened when dry weather follows application, but the reduced effectiveness of herbicides under these conditions need not result in poor weed control since the effectiveness of cultivation is increased in dry weather. The value of herbicides as insurance against the effects of wet weather becomes increasingly greater as the general

effectiveness of cultivation is lowered. In other words the margin for economic utilization of herbicides is greatest when herbicide performance is measured against average or poor cultivation, and is lowered as the effectiveness of cultivation increases. Farm operators who practice good cultural operations may have less need for herbicides even though they are most capable of adapting herbicide technology to production practices. On the other hand, farm operators who fail to control weeds effectively with cultivation may be less inclined to utilize herbicides efficiently and effectively.

Experimental conditions encountered in this study are believed to be typical of those in a large part of the soybean producing area of the state, though it is recognized that with extremely wet soils and heavy weed infestations, mechanical cultivation would have been less effective and as a result, pre-emergence herbicidal treatments more effective in early weed control. It is recognized that future developments in herbicide technology will undoubtedly result in herbicides which can be utilized successfully in soybean production within the economic and practical limits outlined. For the present, however, the role of residual pre-emergence herbicides in soybean production is limited by the cost of herbicides in relation to the expected economic return from controlling weeds, and by the effectiveness and economy of cultivation. The utilization of herbicides presently available, for weed control in soybeans would appear to be economical and practical only in those areas where weed infestations are severe and where previous experience has demonstrated the consistent failure of cultural methods.

SUMMARY

A number of herbicides were evaluated as residual pre-emergence treatments over a 7-year period, with representative annual weed infestations in row-planted soybeans. Techniques employed placed special emphasis on the comparison of herbicide performance with well-cultivated check plots. The major objective of this study and presentation was aimed at evaluating the potential usage of residual pre-emergence herbicides in soybean weed control, rather than detailing the results of herbicide screening tests. Estimates of weed control and soybean seed yield were obtained.

Several herbicides were shown to be useful as supplements to cultivation in controlling annual weeds in beans. The majority of tests showed that herbicides did not greatly enhance the effectiveness of cultivation. This was particularly true when early cultivations were done at shallow depths with a spike-tooth harrow.

The present use and potential role of herbicides is discussed from the aspects of practical and economical weed control in soybean production. The expected yield losses from the competition of nominal infestations and the extent to which herbicides were superior to cultivation are major points discussed. It is recognized that under different weather conditions and with other kinds of infestations, cultivation might have been less effective and the assessment of herbicide performance greater.

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The Effect of Soil Smoothing Devices on the Action of Pre-emergence Herbicides in Soybeans and Corn[1]

R. E. Larson, D. L. Klingman, and O. H. Fletchall[2]

Introduction

A review of literature indicates that there are considerable variations in the results obtained in using herbicides for selective pre-emergence weed control. These variable results have been attributed in part at least to a large number of possible factors, a few of which are: soil type, soil moisture, soil surface condition, rainfall, plant varietal difference, and application variations and errors. In 1952 a study of the literature reporting research studies and recommendations indicated that some method of rolling or smoothing prior to pre-emergence applications might prove to eliminate those variations in results from such applications as could be attributed to the rough, cloddy condition of the soil surface. This was particularly noticeable in early bulletins of the cotton producing states, a number of which (1, 3, 4, 6, and 7) recommended that the soil surface be rolled smooth prior to the application of pre-emergence herbicides for weed control in cotton.

On the other hand, some later reports show that soil smoothing has little effect on the action of pre-emergence herbicides. In 1955 McWhorter et al. (5) tried six soil smoothing devices for pre-emergence weed control in cotton, and reported that there were no significant differences attributable to type of press wheel and that weed control was comparable on loose and pressed soil. Also, Mississippi recommendations for 1955 (2) for pre-emergence treatments for the chemical control of weeds in cotton contains this statement: "Numerous tests for the past three years have shown no advantage in weed control or cotton stands obtained by using a wide roller instead of the regular planter press wheel."

On the basis of the early information it was felt that rolling and/or smoothing prior to application of pre-emergence herbicides in soybeans and corn might also prove advantageous with these crops.

Materials and Methods

An exploratory study of the equipment factors was initiated in 1952. A standard lawn roller 24 inches x 18 inches filled with water was tested on a Mexico silt loam soil. This roller was found to be satisfactory only when the clods had sufficient moisture to break up quite easily. Clods of the soil in these experiments were too dry for effective rolling with this roller in a relatively short time after being

[1]Report of a cooperative study conducted at Columbia, Missouri, by the Missouri Agricultural Experiment Station and the Agricultural Research Service, U. S. Department of Agriculture. Missouri Agricultural Experiment Station, Journal Series No. 1740.

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worked. To increase the weight per unit of ground area, the lawn roller was cut in half and one of the halves filled with concrete. This resulting roller was 12 inches wide, 18 inches in diameter, and weighed approximately 240 pounds. The weight per unit of area was then almost 220% that of the original roller. Field tests with this roller proved that it would break up or push into the ground all clods except the driest large ones.

In order to cope with those few large, dry lumps which the roller did not take care of, it was necessary to design a drag to go ahead of the roller to move such clods to the side. The drag used for the purpose (Figure 1) was made of 2½ x 2½ x ⅜ inch steel angle shaped to form a triangular drag. Two sides of the triangle served to shove the clods and debris off to the sides while the rear side of the triangle aided in partially smoothing the soil surface just ahead of the roller. A 6-inch opening was left at the front to prevent any tendency of the drag to uncover the crop seed.

In operation it was found that some soils adhered to the roller. This was largely overcome by covering the roller with rubber. After all modifications were completed, the drag and roller were used as shown in Figure 1. This equipment provided a surface smooth

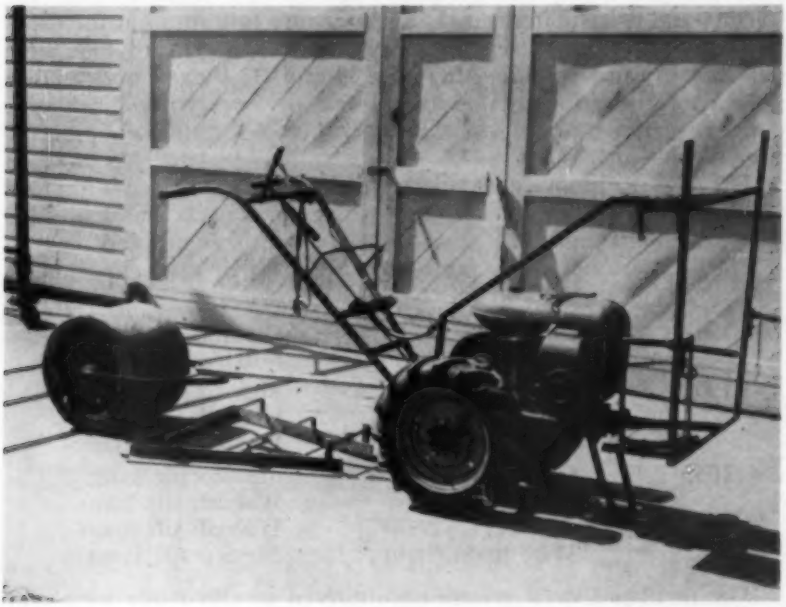

Figure 1. View of drag and roller used for ground surface preparation prior to application of pre-emergence herbicides for weed control in soybeans. In trials on corn the drag and roller were used as separate treatments.

enough to test the factor of soil surface condition as a means of improving the effectiveness of pre-emergence herbicides applied for weed control in soybeans and corn.

The studies reported herein were conducted for 3 years (1953, 1954, and 1955) in combinations with approximately six herbicides each year. The herbicide treatments on the soybeans in this study included various rates of 4,6–dinitro–o–sec–butylphenol (DNBP), isopropyl N–(3 chlorophenyl)carbamate (CIPC), pentachlorophenol, sodium salt (PCP-Na) 2–chloro–N,N–diallylacetamide, N–1–napthyl phthalamic acid, 2–chloro–N,N–diethylacetamide, and 2–chloroallyl diethyldithiocarbamate. Of these the DNBP, CIPC, and PCP-Na were included for all 3 years. The studies on field corn included 1 and 2-pound per acre rates of 2,4–D ester.

In all of the soybean studies the ground was fall plowed then disked and harrowed just prior to planting about May 10 to 30. The beans were usually planted, rolled, and the herbicides applied all in one day. During the season they were cultivated two or three times. Stand counts of soybeans and weeds were taken 4 to 5 weeks after planting. The corn was generally handled in the same manner as the beans. In the soybeans the mechanical treatment comparison was between rolled and non-rolled, whereas in the corn, dragging, by itself, was included as a third treatment.

In general the growing season weather for these studies was warmer and drier than normal. The moisture conditions at the times of treatment varied in that the May months of 1953 and 1955 were deficient in rainfall while May of 1954 had .38 inches more than a normal precipitation of 4.84 inches. For all 3 years the cumulative departure from normal from January 1 shows a deficiency at the time of planting.

The field studies were set up in a split plot design, containing four replications with herbicides, cultivated check and hand weeded checks as main plots and mechanical treatment as subplots.

The field studies were conducted in a total of nine experiments with years, locations, and soil types as follows:

1953	Columbia	Weldon silt loam
	McCredie	Mexico silt loam
1954	Columbia	Mexico silt loam
	Jefferson City	Wabash silt loam
	Elsberry	Wabash silt loam
1955	Columbia	Mexico silt loam
	Jefferson City	Wabash silt loam
	Elsberry	Wabash silt loam
	Wise Bros. Farm	Mexico silt loam

The principal weed grasses encountered in this study were crab grass *Digitaria sanguinalis* (L.) Scop, foxtails *Setaria* spp., barnyard grass *Echinochloa crusgalli* (L.) Beauv., and sedges *Carex* spp. The broadleaved weeds were smartweed *Polygonum penyslvanicum* L., pigweed *Amaranthus* spp., western water hemp *Acnida* spp., lambsquarters *Chenopodium album* L., velvet leaf *Abutilon theophrasti* Medic., and bull nettle *Solanum carolinense* L.

RESULTS

Results of these studies were measured in terms of soybean and corn yields, soybean stand, weedy grass counts, and broadleaved weed counts. Because of drought condition, hail, and shortages of time or labor not all of these measures of results were taken in all experiments. For this reason the results of the experiments included in the tables are not all the same.

The results of the soybean studies in terms of yield, soybean stand, weed grasses, and broadleaved weeds are as given in Tables 1, 2, 3, and 4 respectively. Corn yields are given in Table 5.

Table 1. Soybean yields as affected by pre-emergence rolling.

Mechanical treatment	Yield-bu/A[a]									
	Chemicals and rates-lb/A							Check	Hand weeded check	Av.
	CIPC		DNBP		PCP-Na					
	8	10	6	7½	10	15	20			
Rolled	17.0	16.8	18.1	17.4	16.6	17.5	18.8	12.5	17.6	16.9
Non-rolled	16.6	16.1	18.2	18.9	17.5	19.1	20.3	13.8	20.1	17.8
Average	16.8	16.4	18.2	18.2	17.0	18.3	19.6	13.2	18.8	17.4

LSD 5% level	
For chemical treatment	3.32
For rolling	Not significant
For interaction chemical x rolling	Not significant

[a]Yields are averages for seven uniform experiments as follows:
1955—Elsberry, Jefferson City, Wise Bros., Columbia
1954—Columbia
1953—McCredie, Columbia

Differences in average soybean yields resulting from chemical treatments exceed the 5% level of significance when seven experiments were averaged together (Table 1) The difference between rolling and non-rolling was not statistically significant, however, the data show there was a trend toward decreased yields with the rolling treatment. An analysis of the results for some individual

Table 2. Stand of soybeans as affected by pre-emergence rolling.

Mechanical treatment	Number of soybean plants in 18 feet of row[a]									
	Chemicals and rates—16/A							Check	Hand weeded check	Av.
	CIPC		DNBP		PCP-Na					
	8	10	6	7½	10	15	20			
Rolled	86.1	76.9	89.8	82.9	94.3	95.8	91.4	97.8	91.8	89.6
Non-rolled	90.8	84.0	89.3	98.0	100.7	95.1	100.6	100.2	101.9	95.6
Average	88.4	80.4	89.6	90.4	97.5	95.4	96.0	98.0	96.8	92.6

LSD 5% level	
Chemical treatment	Not significant
Rolling	Not significant
Interaction chemical x rolling	Not significant

[a]Average stand for seven uniform experiments as follows:
1955—Columbia, Jefferson City, Wise Bros.
1954—Columbia, Jefferson City
1953—Columbia, McCredie

experiments showed the difference between rolled and non-rolled treatments exceeded the one per cent level of probability. In two of seven individual experiments, rolling improved the yields, while in five experiments, rolling reduced yields.

The soybean stand counts show the same general trend as the yield results (Table 2). These data on the basis of some individual experiments showed a significant reduction in stand due to rolling. In some trials the stands on the plots treated with CIPC and DNBP were significantly less than the untreated check and also the hand weeded check. These differences were not significant in a consolidated analysis of all experiments.

The chemical treatments gave reductions in weed grass stands that are significant at the one percent level for all experiments (Table 3).

Table 3. Weed grass control in soybeans as affected by pre-emergence rolling.

Mechanical treatment	Number of weed grasses in a 6-inch band over 18 feet of row[a]									
	Chemicals and rates—lb/A								Hand weeded check[b]	Av.
	CIPC		DNBP		PCP-Na			Check		
	8	10	6	7½	10	15	20			
Rolled	5.0	2.3	32.6	20.0	59.5	19.5	11.8	104.2	130.4	42.8
Non-rolled	5.4	1.6	27.2	22.4	45.4	18.8	20.8	90.0	69.5	33.4
Average	5.2	2.0	29.9	21.2	52.4	19.2	16.3	97.1	100.0	38.1

LSD 5% level	
Chemical treatment	58.6
Rolling	Not significant
Interaction chemical x rolling	Not significant

[a]Average weed grass stand for five uniform experiments as follows:
1955—Columbia, Wise Bros.
1954—Columbia, Jefferson City
1953—Columbia
[b]Weeds were counted before they were removed.

Table 4. Broadleaved weed control in soybeans as affected by pre-emergence rolling.

Mechanical treatment	Number of broadleaved weeds in a 6-inch band over 18 feet of row[a]									
	Chemicals and rates—lb/A								Hand weeded check[b]	Av.
	CIPC		DNBP		PCP-Na			Check		
	8	10	6	7½	10	15	20			
Rolled	26.0	42.4	47.6	34.8	60.9	36.2	25.1	140.2	106.5	57.7
Non-rolled	24.0	45.0	36.7	29.6	40.2	43.2	24.8	134.8	79.2	50.8
Average	25.0	43.7	42.2	32.2	50.6	39.7	25.0	137.5	92.8	54.2

LSD 5% level	
Chemical treatment	55.7
Rolling	Not significant
Interaction chemical x rolling	Not significant

[a]Average broadleaved weed stand for five uniform experiments as follows:
1955—Columbia, Wise Bros.
1954—Columbia, Jefferson City
1953—Columbia
[b]Weeds were counted before they were removed.

Rolling gave less weed grass control than non-rolling with the difference being significant at the 5 percent level in some of the individual experiments, but not significant for a grouping of all experiments. The principal weed grass in the study was the shallow germinating crabgrass. It is assumed the packing action of the roller tended to be advantageous to the seed germination of this weed.

The broadleaved weeds were significantly reduced by chemical treatment (Table 4). The control of weeds was significantly increased as compared to the cultivated checks in both the individual experiments and as an average of all experiments at the 1% level. There was less control of broadleaved weeds in plots rolled than in those not rolled with the difference being significant at the 5% level for some of the individual experiments. The difference was not significant for the average of all the experiments.

The differences due to interaction of chemical x rolling were not significant at the 5% level for any of the four measures of results.

In the study of the rolling treatment on corn, the yield differences due to mechanical treatments were not significant at the 5% level for the average of all experiments (Table 5). The chemical treat-

Table 5. Corn yields as affected by pre-emergence rolling and dragging.

Mechanical treatment	Yield—bu/A*			
	Check	2,4-D ester		Average mechanical treatment
		1 lb/A	2 lb/A	
None	53.69	66.84	66.68	62.40
Drag	53.61	67.23	68.91	63.25
Roll	55.99	69.30	69.83	65.04
Av. chemical treatment	54.43	67.79	68.47	63.56

LSD 5% level	
Chemical treatment	3.6
Smoothing treatment	Not significant
Interaction chemical x smoothing	Not significant

*Average yields for five uniform experiments as follows:
1955—Elsberry, Jefferson City, Columbia
1954—Elsberry, Columbia

ments increased the yields with the difference being significant at the 1% level in the individual experiments and at the 5% level over all experiments. The interaction differences of chemical x mechanical treatment were not significant.

DISCUSSION

The average results of this experimental study would indicate that rolling and smoothing prior to the application of pre-emergence herbicide tends to decrease the soybean yields and stands and also reduce the effectiveness of the herbicides for controlling the weeds. Exceptions to this conclusion were noted in the 1954 experiment at Columbia and the 1953 experiment at McCredie. In both of these tests the rolled plots yielded more than those not rolled. The surface soil in both cases was very dry at the time of planting such that the

roller improved the emergence and the stand by packing the soil more firmly around the seed. On the other hand in the experiments where the soil was moist or wet, the increased packing and resulting soil crusting reduced or delayed the emergence of the soybeans. Inasmuch as corn is less affected by such soil crusting than are the soybeans, the rolling tended to give an average benefit rather than a decrease.

In all individual experiments where weeds were a problem, almost all of the herbicide treatments increased the yields.

The rolling tended to reduce slightly the effectiveness of the herbicides on both the broadleaved and grass weeds because of the increase in germination of weeds in the rolled plots. This is evidenced by the increase in weed grass stand in all but one of 10 check treatments in the five experiments. The broadleaf weed count was greater in all but two of 10 check treatments.

Similar conclusions can be drawn from the corn studies where the weed counts show that rolling tended to increase the weed stand. In these studies where dragging was included as a separate treatment, it was found that this method did not increase the weed stand as much as did the rolling.

SUMMARY

1. A three-year study totaling nine experiments was conducted to determine the effect of rolling and smoothing the soil surface prior to chemical application as it might influence the selective action of pre-emergence herbicides in soybeans and corn.

2. On soybeans the rolling tended to decrease the stands and yields.

3. In soybeans the rolling tended to reduce the amount of weed control affected by the herbicides.

4. The rolling and smoothing tended to increase the yields of corn.

5. Pre-emergence herbicides gave increased yields of soybeans and corn.

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The Effect of Day and Night Temperature on Growth, Foliar Wax Content, and Cuticle Development of Velvet Mesquite

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THE mesquite problem on southern Arizona ranges has been comprehensively described by Parker and Martin (9), and certain ecological relationships of this noxious tree, insofar as are known, have recently been considered by Glendening and Paulsen (5). Although a serious problem only in the states of Arizona, New Mexico, and Texas, at least one of the three common varieties of *Prosopis juliflora* now may be found in each of eight southwestern states (2). Its progressive invasion is unquestioned.

One of the principal factors affecting ultimate distribution of mesquite is temperature. A study of the effect of day and night temperatures upon growth should indicate the optimum temperature requirements of the plant and the extreme temperature conditions under which it may exist, as well as providing basic data from which ultimate latitudinal and altitudinal migration may be estimated. Studies described in the present paper, however, deal more specifically with the effect of temperature upon anatomy and cuticular development. The cuticle has been well establishd as a distinct barrier to optimum herbicidal absorption. Herbicidal absorption and translocation in mesquite and factors affecting these phenomena have been described by several investigators (3, 4, 6).

METHODS AND MATERIALS

All plants were grown in the air-conditioned greenhouse of the Earhart Plant Research Laboratory at the California Institute of Technology (10). Scarified seeds of velvet mesquite *(P. juliflora* var. *velutina)* were germinated and grown in vermiculite contained in plastic containers 9 x 9 x 15 cm in size. In order to minimize genetic variation, all seed were progeny of a single parent. After germination, plants were thinned to 1 per container, 16 being grown under each temperature condition. Because of space limitation, the number of plants under each condition was later reduced to 12.

With the exception of air temperature, plants in all temperature combinations received identical treatment, and were subjected consecutively to 8 hours of natural light, 8 hours of artificial light, and 8 hours of darkness. The artificial light source consisted of daylight fluorescent tubes operated under boosted amperage in combination with incandescent lamps (10). The resultant illumination had a spectral distribution similar to daylight and an intensity of about 1,300 foot-candles at the plant apices.

Plantings were irrigated with deionized water until seedlings

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broke through the surface, after which the water was supplemented with Hoagland's nutrient solution. The six temperature conditions to which the plants were subjected are shown in Table 1.

Table 1. Shoot and root weight, height, and number of leaves on velvet mesquite plants grown at various day and night temperatures.

Temperature °C		Mean weight per plant at age of 97 days—g				Mean height of plants at ages indicated—cm			Mean number of leaves on plants at ages indicated		
		Fresh weight		Dry weight							
Day	Night	Shoot	Root	Shoot	Root	33 days	54 days	86 days	33 days	54 days	86 days
30	26	11.76	1.83	3.88	0.47	33.3	63.5	164.5	17	36	68
30	23	6.36	1.23	2.05	0.29	28.2	53.3	109.0	15	25	44
30	20	4.02	0.87	1.27	0.19	21.2	42.6	85.0	9	20	35
26	23	10.90	1.66	3.40	0.42	29.1	65.1	145.0	14	29	51
26	20	2.81	0.67	0.93	0.17	19.2	42.0	67.0	9	18	27
26	17	1.49	0.47	0.49	0.10	13.1	26.1	52.5	6	13	22

Eleven plants from each group were harvested at the age of 97 days, at which time fresh and dry weights of both shoots and roots were measured. In addition, height and leaf count of three representative plants from each temperature group were taken at various intervals during the life of the plants.

After dry weight had been obtained, the plant tops were separated into component parts—the leaflets from the rachises and petioles, and the latter from the stems. Leaflets from all plants of each group were ground in a Wiley mill to pass a 20-mesh screen, dried again at 70° C, and weighed.

In addition to the leaflets which were ground for use in total wax determination, a portion from each temperature group was maintained intact for enzymatic cuticle isolation by means of pectinase (8). Included in the isolation attempt were dried mesquite leaflets from the temperature experiment, fresh leaflets from both greenhouse-grown plants and large field trees, and leaves of *Citrus reticulata* (tangerine). Leaflets were either left intact or dissected into 2-mm-square sections before incubation with the enzyme. (One-cm discs were punched out in the case of citrus leaves.) Solutions were maintained sterile with 1,000 ppmw merthiolate.

Wax was extracted from ground and weighed leaflets for 8 hours with 60 to 80° C ligroine by means by Soxhlet extractors (1, 7). After concentration of the extract, acetone was added and waxes thus precipitated as an acetone-insoluble fraction, were recovered by centrifugation. The supernatant contained the non-wax fatty substances (i.e., fats, phospholipides, carotenoids, chlorophylls, etc.). By distillation of the excess solvent, the wax and the non-wax fatty substances were recovered, and yields thereby determined.

Melting point of the waxes was determined in duplicate, using the drop method of Kurtz.[2] Agreement was always within 0.5° C for each sample. Iodine number, a measure of the degree of unsaturation,

[2]Kurtz, E. B., Jr. Progress report No. 2 to S. C. Johnson and Son. 8 pp. 1949.

was determined according to the method of Yasuda (11). Each determination (also in duplicate) was made on about 10 mg of wax, weighed to the nearest 0.1 mg. As a check, the iodine number was determined on a 10.8 mg sample of oleic acid. The calculated value of 95.8 compared fairly well with the theoretical value of 90.0.

At the time of harvest one representative plant from each temperature group was preserved in FPA killing solution (formalin, 10 parts; propionic acid, 5 parts; 70 percent ethanol, 85 parts—all by volume). Leaves and stems from the central portion of these plants were prepared for microscopic examination by dehydration through a butyl alcohol series, embedding in Tissuemat (M.P. 60 to 63° C), sectioning at 10 μ by means of a rotary microtome, and staining with safranin O, fast green and orange G. After mounting with Permount, photomicrography was accomplished with a 35mm Kine-Exakta.

Since the possibility exists that the constituents of leaf-cuticle from a very young or greenhouse-grown plant may be partially removed by xylol during the preparation of microscope slides, sections were also prepared on the freezing microtome. With this method, organic solvents are not needed to remove the embedding paraffin from the section.

EXPERIMENTAL RESULTS

Effect of Day and Night Temperature on Growth.

Both fresh and dry weights of shoot and root at time of harvest (age, 97 days), as well as height and leaf count at several stages during growth appear in Table 1. Plants were remarkably uniform within groups. Growth extremes for each temperature are shown in Figure 1.

The percentage of dry to fresh weight was calculated for shoots and roots in the six temperature conditions. Values ranged only from 31.2 to 33.2 percent in the case of shoots, and appeared to have no particular relation to plant weight or temperature distribution. Values for roots ranged from 21.2 to 25.5 percent, with higher values being at the higher night temperatures. Actual shoot and root growth, as determined by either weight or height, or by leaf count, was greatest at a day temperature of 30° C and a night temperature

Table 2. Leaf weights and wax and non-wax fatty substance analyses of mesquite leaves from plants grown under six conditions of day and night temperature.

Temperature °C		Weight of leaflets extracted—g	Wax recovered —mg	Non-wax fatty substances recovered —mg	Ratio of wax to non-wax fatty substances as a percent	Percent yield on dry weight basis		Wax melting point—°C	Iodine number of wax
Day	Night					Wax	Non-wax fatty substances		
30	26	8.55	175	228	76.8	2.05	2.67	81.5	23.4
30	23	5.49	103	133	77.5	1.88	2.42	81.4	14.4
30	20	3.42	41	96	42.8	1.20	2.81	79.0	19.0
26	23	7.63	114	174	65.5	1.49	2.28	81.2	19.9
26	20	2.28	32	67	47.8	1.40	2.94	79.2	17.0
26	17	1.61	9	53	17.0	0.56	3.30	77.5	19.2[a]

[a]Based on a single determination because of the small quantity of material available.

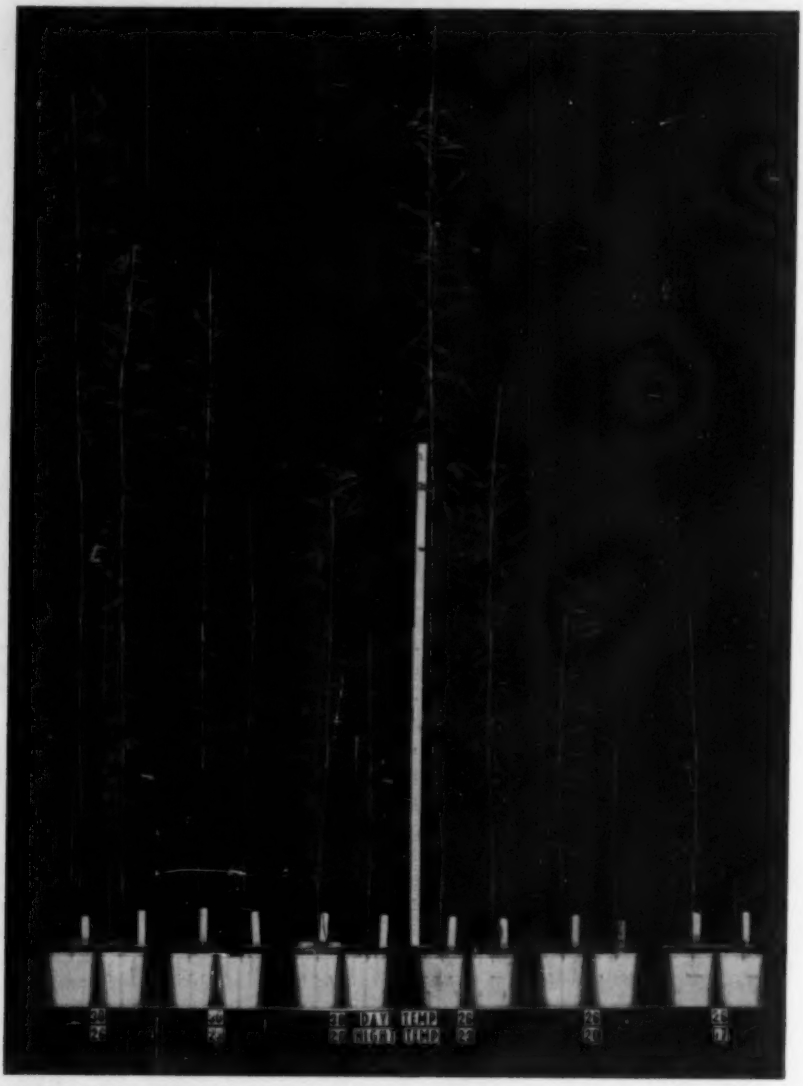

Figure 1. Velvet mesquite plants, 97 days of age, grown under the six combinations of day and night temperature (°C) indicated. Extremes only are shown for each temperature group of 12 plants.

of 26° C. These are the highest temperatures normally available in the greenhouse, and velvet mesquite is one of a very few species of plants which has exhibited maximum growth at these high temperatures. Relative root growth at the various temperature combinations is illustrated in Figure 2.

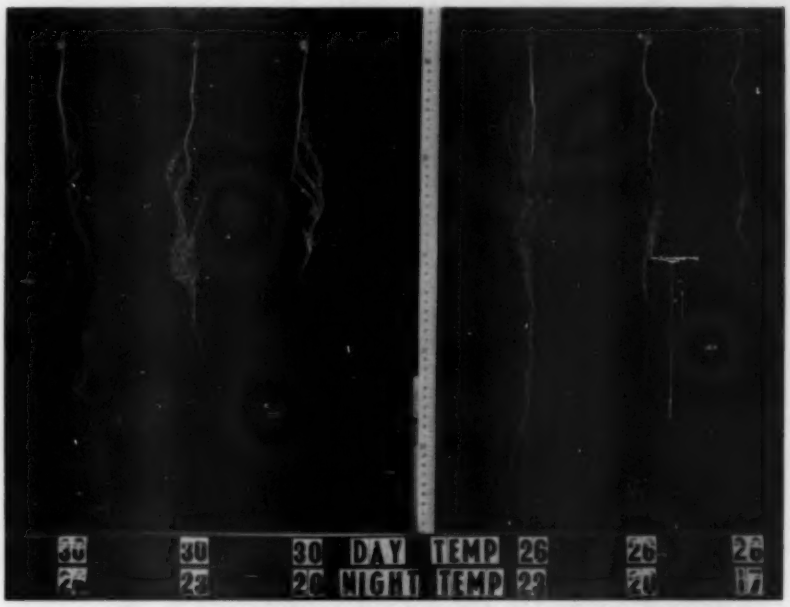

Figure 2. Representative growth of velvet mesquite roots under the six temperature (°C) combinations shown.

Effect of Temperature on Wax Content and Quality.

The yield of wax and non-wax fatty substances from leaves of plants grown under the different temperature conditions is shown in Table 2. In addition, the melting point and iodine number of the wax and the ratio of wax to non-wax fatty substances is also indicated. Total wax content, as a percentage of dry leaf weight, was greatest at both high day and high night temperatures. The content of non-wax fatty substances, on the other hand, was less influenced by temperature but was maximum at the lowest night temperatures. Melting point of the wax ranged from 77.5 to 81.5° C, and was directly correlated with both day and night temperatures at which the plants were grown. Iodine number of the wax was lowest at median night temperatures, in each of the two day temperature groups (30° and 26° C). Finally, the ratio of wax to non-wax fatty substances was decreased by both low day and low night temperature.

As to cuticle isolation by enzymatic digestion, the citrus discs readily released intact cuticle from both surfaces during the first day of incubation. However, none of the mesquite leaflets (fresh or dry, cut or intact) released cuticle, even after five days of incubation and shaking. Examination of the leaflets under magnification indicated that enzymatic decomposition of the epidermal and mesophyll cell walls was adequate, and that failure of cuticle isolation was apparently due to the simple physical barriers imposed by the minute size of the leaflets, and the extremely thin, fragile nature of the cuticles.

Effect of Temperature and Other Factors on Cuticle Development.

No striking differences in anatomical structure could be established between leaflets of plants grown under the different temperature conditions. Strangely enough, no cuticle could be detected on either the upper or lower surface of any of the leaves examined, even after staining with safranin O, methylene blue, crystal violet, acid fuchsin or erythrosin B. In a few cases, a trace of cuticle (less than 1 μ in thickness) was suggested by a slight tinge resulting from certain stains which are strongly absorbed by cutin. A leaflet transection demonstrating lack of cuticle on both surfaces is shown in Figure 3A. This section was prepared from a plant grown under the 30° C day and 26° C night temperature regime. Leaflets from the other five temperature conditions had a similar appearance and also generally lacked cuticle. Sections prepared on the freezing microtome and stained at various intensities also failed to show a distinct cuticle.

In order to ascertain the cuticle development on leaflets growing under field conditions, a collection was made on May 2, 1957, and sections prepared for microscopic examination. A photomicrograph which clearly indicates a well-developed cuticle about 8 μ in thickness on the upper surface and 1–2 μ on the lower surface is shown in Figure 3B. In addition to being thinner, the lower cuticle in this case did not absorb the red safranin stain to any marked degree, suggesting a chemical nature different from that of the upper cuticle. This degree of difference between the upper and lower cuticles is not common in mesquite leaflets. A transection of a leaflet collected February 12, 1957, and possessing a well developed lower cuticle of 8–10 μ thickness is shown in Figure 3C. Although not visible, the upper cuticle was of equivalent thickness. Because of the mild 1956–57 winter, many mesquite trees did not defoliate as they normally do between December and March. The above section was from such a leaf that had over-wintered and consequently was almost a year old.

In cooperative research, Hoshaw[3] has investigated the morphological development of the mesquite leaf at frequent intervals between late March and late October. He found that maximum cuticular development occurred only after leaf tissue maturation. The cuticle, which was extremely thin on March 31, reached several microns in thickness by late April, and as much as 15 μ by mid-June. At the latter stage, it was approximately one and one-half times the thickness of an epidermal cell, and did not thicken further during the summer and fall.

Stems of plants from the temperature experiment, in contrast to the leaflets, had a distinct cuticle. Examination of numerous sections from plants grown under the 30 to 26° C temperature condition indicated that stem cuticle thickness (from the center portion of the plant) ranged from 3 to 5 μ, and was generally from one-fourth to

[3]Hoshaw, Robert W. Studies on the anatomy of mesquite leaves. 19 pp. Bot. Dept., U. of Ariz. 1955. (Cooperative study between the Ariz. Agr. Exp. Sta. and U. S. Forest Service.)

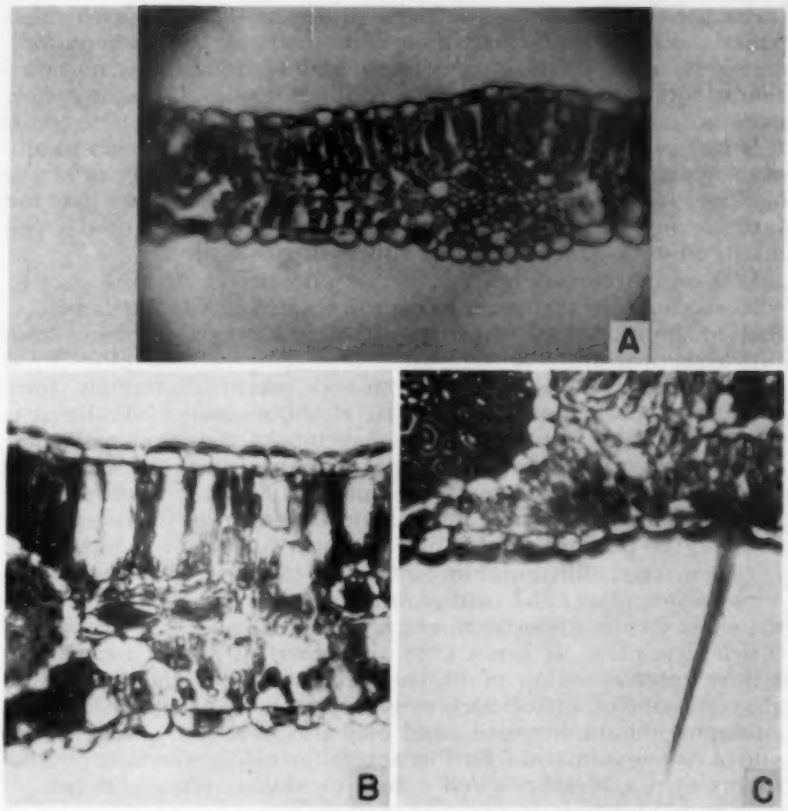

Figure 3. Transections of mesquite leaflets from plants growing under various conditions. A. A 97-day-old seedling grown in a 30° C day and 26° C night. Note midvein and lack of cuticle on both upper and lower leaflet surfaces. Leaflet cuticle was also lacking on plants grown under other temperature conditions (× 215). B. Collected from a field mesquite May 2, 1957. Upper cuticle averaged about 8 μ in thickness, but lower cuticle was only 1–2 μ thick and stained only slightly. Note water storage cells and large intercellular spaces in both palisade and spongy parenchyma. (× 230). C. Old leaflet collected February 12, 1957, from foliage which had overwintered. Well developed lower cuticle (shown) was up to 8–10 μ in thickness, as was the upper cuticle. Note highly cutinized trichome (× 245).

one-third the thickness of the epidermal cells. Stem cuticle of plants grown under the 26 to 17° C temperatures was slightly thinner, ranging from 2 to 3 μ in thickness and averaging perhaps one-fifth the thickness of the epidermal cells.

Discussion

Although velvet mesquite has been shown to grow most rapidly at a day temperature of 30° C and a night temperature of 26° C, its ability to grow fairly well at considerably lower temperatures is of

interest. Other studies indicating its ability to survive for extended periods at day temperatures approaching 50° C, and to germinate and grow well within an extremely wide range of soil moisture conditions, clearly demonstrate some of the reasons for its aggressive invasion.

Since virtually no surface cuticle was visible on the leaves of any of the greenhouse-grown plants, the fact that a greater wax yield was obtained from plants grown at high temperatures suggests that the variance in foliar wax yield at different temperatures results primarily from the content of wax dispersed within the cell.

Wax metabolism is not completely understood. Several lines of evidence indicate that wax is not translocated *per se* but is synthesized at or near its point of deposition. Whether the thicker stem cuticle on mesquite plants grown at high temperatures results from an increased rate of synthesis from wax precursors (acetate, long chain fatty acids, mono and dihydric alcohols, etc.), or whether it is due to an increased translocation of certain of the lower molecular weight precursors at the high temperatures is open to question. The considerably greater content of non-cuticular wax found in the leaflets of the high-temperature plants suggests the former process as being the primary temperature-dependent one.

The marked difference in cuticle development between greenhouse-grown plants and field-grown plants poses the question as to the exact factors (other than temperature) which create maximum cuticle deposition. It is not known whether ultraviolet irradiation, a large spectral region of which is eliminated by the greenhouse glass, is a major factor. Degree of soil moisture stress, prevailing atmospheric humidity, and wind may also have some influence on rate of cuticle formation. Further studies involving the effect of these factors on wax synthesis and cuticle deposition (cuticle is not all wax) would be desirable.

Because of the inhibited cuticle formation in greenhouse-grown mesquite (which undoubtedly occurs in many other greenhouse plants), it may well be asked whether such plants will give representative responses to herbicides formulated for field use. Experience at this station has generally indicated that they do. However, discrepancies in response between greenhouse and field mesquite have been noted in certain cases. Most variation appears to be between formulations of a specific herbicide, and not between herbicides themselves. For example, at certain concentrations the sodium salt and amine formulations of 2,4,5–T are translocated far more readily than any of its esters in greenhouse seedlings. Although a high percentage of velvet mesquite plants have been killed in the field with sprays of amine salts of 2,4,5–T, these forms do not give as consistent results as the esters.

In order to kill a mesquite plant readily with 2,4,5–T, both absorption and translocation must be optimum. The data reported herein, along with the results of certain other experiments, suggest that the strongly influencing factor imposed by absorption is markedly minimized in the case of greenhouse-grown seedlings. Consequently, such

plants may well serve as valuable tools where the basic objective of research is aimed toward the study of translocation (This statement is not meant to infer that the problem of absorption is completely absent in greenhouse plants). The added factor of absorption which is present to a more marked degree in field plants might be said to superimpose a second problem and thus to increase the complexity in studies involving the overall effect of a herbicide. Nevertheless, in any final evaluation, field-grown plants would seem the wiser choice, where both limiting factors mentioned above must be overcome.

SUMMARY

Velvet mesquite seedlings were grown to an age of 97 days under six different conditions of day and night temperature, ranging from 30° C to 17° C. Plants maintained at a 30° C day temperature and 26° C night temperature showed the most rapid growth response, as measured by fresh or dry weight, height, or leaf count.

Total wax content of the leaflets was highest in plants grown at the higher temperatures—both day and night. The content of non-wax fatty substances, on the other hand, was highest in plants grown at the lower night temperatures. Melting point of the wax was directly correlated with both day and night temperatures, whereas the iodine number was influenced predominantly by the night temperatures. Highest iodine numbers were found at the extremes of night temperatures, with median night temperatures resulting in lower values.

Although field-grown mesquite was shown to have leaflets with a well-developed cuticle, the experimental greenhouse plants generally did not possess a visible cuticle. Stems of the greenhouse mesquite, however, did have a distinct cuticle of 2 to 5 μ thickness. Data from various experiments, along with the above mentioned observation of cuticular development, suggest that the greenhouse plant is a valuable tool for studies on translocation—principally because the problem of absorption is greatly minimized. Final evaluations, however, where an herbicide must demonstrate its ability to overcome the limiting factors imposed by translocation *and* absorption, would seem to be better conducted under conditions similar to those encountered in the field.

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An Evaluation of the Herbicidal Efficiency of Combinations of ATA With Dalapon, Monuron, and Several Other Chemicals[1]

T. J. Sheets and O. A. Leonard[2]

In many areas of the southwestern states where cotton is a major crop, the use of 2,4–dichlorophenoxyacetic acid (2,4–D) is hazardous. Its use is restricted by law in many localities during the growing season. In these areas many perennial broad-leaved weeds which are susceptible to 2,4–D, at least to some degree, grow in abundance. Because of extreme arid conditions and other factors these weeds have not responded favorably to soil sterilants. There is urgent need for more effective herbicides for these weeds.

The experiments reported here were undertaken to obtain leads for more effective control of annual and perennial weeds. The specific objectives may be summarized as follows: (a) to determine the effect of mixtures of 3–amino–1,2,4–triazole (ATA) and sodium 2,2–dichloropropionate (dalapon, sodium salt) and mixtures of ATA and compounds structurally related to dalapon on kidney beans and barley, (b) to study the effect of a series of unsubstituted carboxylic acids on the herbicidal activity of ATA, (c) to find the most effective ratio of concentrations of the chemicals, and (d) to determine the types of plant response to mixtures of ATA and the sodium salt of dalapon and of ATA and 3–(*p*–chlorophenyl)–1,1–dimethylurea (monuron); i.e., whether the effects were additive, less than additive or synergistic.

The sodium salt of dalapon and ATA have shown promise as herbicides on certain annual and perennial weeds. Early in 1955 interest in combinations of ATA and dalapon as foliar sprays developed (1, 8, 9, 11, 12). Mixtures of ATA with sodium 2,2,3–trichloropropionate (2,2,3–TPA, sodium salt), 2,4–D, and 2,4,5–trichlorophenoxyacetic acid (2,4,5–T), and monuron have also been investigated during and/or since 1955 (6, 7, 9, 11).

Combinations of ATA and the sodium salt of dalapon reduced the stand of established Johnson grass *(Sorghum halepense* (L.) Pers.) but did not appear to produce synergistic effects (3). Anderson (1) reported that the addition of ATA to the sodium salts of dalapon and 2,2,3–TPA did not appear to alter the effects of these herbicides on Johnson grass. Hauser and Thompson (5) stated that mixtures of ATA and the sodium salt of dalapon and ATA and the sodium salt of 2,2,3–TPA were the most phytotoxic treatments on established Johnson grass 2 weeks after spraying. Thirty days after spraying phytoxicity from the mixtures was less than comparable rates of the chlorinated propionic acid derivatives alone. Tafuro and Beatty

[1]Cooperative investigations of the Crops Research Division, ARS, USDA, and the California Agri. Exp. Station.

[2]Research Agronomist, Crops Research Division, ARS, USDA, Botany Dept., University of California, Davis and Associate Botanist in the Expt. Station, University of California, Davis.

(11) reported that the effectiveness of the sodium salt of dalapon and the sodium salt of 2,2,3–TPA on seedling Johnson grass plants was increased when ATA was used as an additive. Pavlychenko stated that combinations of ATA and the sodium salt of dalapon and ATA and the sodium salt of 2,2,3—TPA were definitely more effective on quackgrass *(Agropyron repens* (L.) Beauv.) than either used alone (8). Of the two combinations the ATA and the sodium salt of dalapon mixture was the most effective. Mixtures of ATA with 2,4–D and 2,4,5–T on woody plants and ATA and 2,4–D on nutgrass (*Cyperus rotundus* L.) have not been promising (4, 7). Early observations of Canada thistle (*Cirsium arvense* Scop.) treated with a combination of ATA and monuron were somewhat encouraging (6).

METHODS AND MATERIALS

The experiments were conducted in the greenhouse. Randomized block experimental designs were used. Bermuda grass (*Cynodon dactylon* (L.) Pers.) rhizomes were sprigged in No. 10 metal cans and the plants allowed to develop for approximately 6 months prior to treatment. All other test plants were grown in No. 2.5 metal cans or in some cases 4-inch pots. Kidney beans (*Phaseolus vulgaris* L.) were thinned to 2 plants per can about 6 or 7 days after seeding. The plants were selected for uniformity, and the herbicidal solutions applied when the primary leaves were fully expanded. Barley *(Hordeum vulgare* L.) was thinned to a uniform number within a replication (between 10 and 15 plants), selected for uniformity in size, and treated when the plants were approximately 15 cm high. Ten to 12 days elapsed between seeding and treating. Twenty-five barnyard grass (*Echinocloa crusgalli* (L.) Beauv.) seed were planted per can. These plants were not thinned but were selected for uniformity of size and number per can prior to treatment. The barnyard grass plants were treated 12 to 14 days following seeding when they were approximately 15 cm high.

The response of barley and kidney beans to mixtures of ATA and the sodium salt of dalapon alone and in combination was studied. This test contained 3 replications.

A comparative study of the effect of mixtures of ATA with dalapon, trichloroacetic acetic (TCA), 2,2,3–TPA, the sodium salts of these 3 acids, and the sodium salt of monochloroacetic acid (MCA) was conducted. The various combinations contained equimolar amounts of the chemicals, i.e., each chlorinated acid and chlorinated salt, in mixture with ATA, was equal in molarity to the ATA in the solution (Table 2). This accounts for the unequal rates of the various compounds. Barley and kidney beans were the test plants. Four replications were used.

Combinations of ATA and unsubstituted carboxylic acids of the series, acetic through heptanoic, were mixed at equimolar amounts to 1.0 lb/A rates of ATA, and the solutions applied to barley and kidney beans. A mixture of the sodium salt of dalapon and ATA was included for comparison. There were 3 and 5 replications, respectively, for barley and kidney beans.

The tests on herbicidal synergism were designed similar to those of Crafts and Reiber (2). The type of response of barley, kidney beans, and barnyard grass to mixtures of ATA and the sodium salt of dalapon and to mixtures of ATA and monuron was determined. The response of Bermuda grass to combinations of ATA and the sodium salt of dalapon was also studied. From the results of earlier tests a rate which reduced the fresh weight of the test plant by about 50 per cent was chosen for each of the two chemicals in the combination. The various combinations were prepared by decreasing one herbicide in one direction through a series, while the other herbicide was increased in the same direction from zero to the rate which reduced growth by approximately 50 per cent (see Figures 1 and 2 for the series of rates for different species). In all cases the lower rates of the herbicides were applied alone as well as in the mixtures. Bermuda grass and barnyard grass experiments contained 5 replications; and the barley and kidney bean tests were replicated 9 and 10 times, respectively.

In the first three tests commercial formulations of ATA, the sodium salt of dalapon, and the sodium salt of TCA were used. All other compounds used in these tests were technical grade.

In the studies on herbicidal synergism 88.5 per cent nonformulated ATA, the sodium salt of dalapon containing 68 per cent of the acid without wetting agent, and the 80 per cent wettable powder formulation of monuron were used. All solutions for the synergism studies contained 1.8 ml of X–77 per gallon.[3]

The soil surface in pots containing kidney beans, barley, or barnyard grass was covered with vermiculite prior to spraying to prevent contact of the spray solutions with the soil. The vermiculite was removed after the sprays dried but prior to the first watering. The herbicides were applied as aqueous solutions at a rate corresponding to 40 gpa with an experimental spraying table described by Shaw and Swanson (10).

Measurements of plant response consisted of fresh weights and chlorosis ratings. Fresh weights of kidney beans were the weights of the growth above the primary leaf node of two plants. Fresh weights of barley and barnyard grass were the weights of all growth on a culture above the soil level. The chlorosis ratings were visual estimates of the chlorosis developing following treatment based on a zero to ten rating scheme: 0 = no chlorosis; 10 = complete chlorosis. All data were collected between 2 and 5 weeks after treatment unless otherwise noted.

RESULTS

Mixtures of ATA and the sodium salt of dalapon. Marked reductions in fresh weights of barley and kidney beans were caused by

[3]Experimental samples of herbicides used in these investigations were supplied by the following companies: the American Chemical Paint Company, Ambler, Penn.; the American Cyanamid Company, New York, N. Y.; the Dow Chemical Company, Midland, Mich.; and E. I. DuPont de Nemours and Company, Wilmington 98, Delaware. The spreader-sticker, X–77, was supplied by Colloidal Products Corporation, Sausalito, California.

several of the ATA-dalapon mixtures (Table 1). The effects of the two herbicides applied as a mixture to the foliage of both test plants appeared to be additive. The addition of the sodium salt of dalapon to ATA solutions at sublethal doses of the chemicals, decreased chlorosis development in primary leaves of beans treated with such mixtures and tended to increase the total chlorosis development in the growth above the primary leaves.

Mixtures of ATA with several compounds structurally related to dalapon. The data from this test are reported in Table 2. Mixtures

Table 1. The response of barley and kidney beans to mixtures of ATA and the sodium salt of dalapon.

Application rate lb/A[a]		Barley[b]	Kidney beans[b]		
			Chlorosis ratings		Fresh weight in gms.
ATA	Dalapon-sodium salt	Fresh wt. in gms.	Primary leaves	Growth above primaries	
0.0	0.39	8.4	0.0	0.0	8.0
0.0	0.79	8.4	0.0	0.0	5.6
0.0	1.57	8.4	0.0	0.7	5.7
0.0	3.14	7.4	0.0	0.0	.5
0.4	0.0	8.2	1.7	2.0	6.5
0.4	0.39	6.8	3.3	7.3	4.7
0.4	0.79	6.1	2.0	7.7	4.6
0.4	1.57	3.8	1.0	10.0	4.3
0.4	3.14	1.5	0.0	9.3	1.7
0.8	0.0	6.2	5.7	6.7	4.5
0.8	0.39	4.7	4.0	8.3	3.6
0.8	0.79	3.2	4.7	9.7	4.2
0.8	1.57	3.3	3.0	9.7	2.7
0.8	3.14	1.4	1.3	9.3	2.0
1.6	0.0	3.2	6.3	9.0	4.0
Untreated		9.3	0.0	0.0	6.9
LSD at the 5% level		1.9	2.1	2.5	1.6
LSD at the 1% level		2.5	2.8	3.3	2.1
CV	%	20	37	20	23

[a]Rates of ATA are in lb/A of active 3-amino-1,2,4-triazole.
Rates of dalapon are in lb/A of the sodium salt.
[b]The chlorosis ratings were made 2 days and 7 days after treatment, respectively, for primary leaves and growth above primary leaves. Fresh weights were determined 3 weeks after treatment.

containing the sodium salt of dalapon, the sodium salt of 2,2,3–TPA, and dalapon in combination with 1.0 lb/A of ATA, produced the greatest weight reductions of the growth above the primary leaf node of kidney beans. However, the sodium salts of dalapon and 2,2,3–TPA were quite effective alone on kidney beans. The addition of a penetrating agent[4] at a concentration of 0.5 per cent by volume to the solutions for the low rates listed in Table 2 did not alter the effects of these treatments on the fresh weights of barley and kidney beans.

Combinations of ATA and unsubstituted carboxylic acids. Weights of barley were reduced more by ATA-carboxylic acid mixtures than

[4]The penetrating solution contained three parts Mentor 28 (non-toxic oil, viscosity 36) and one part Trem 618 (non-ionic emulsifier).

Table 2. The response of barley and kidney beans to mixtures of ATA and several chlorinated acetic and propionic acids and sodium salts of the acids.

Application rate—lb/A[a]			pH of spray solutions	Fresh weight in gms.[b]	
ATA	Chlorinated acetic and propionic compds.			Barley	Kidney beans
0.0	1.39	MCA, sodium salt	4.1	19.5	9.1
0.0	2.21	TCA, sodium salt	9.5	20.6	9.2
0.0	1.96	Dalapon, sodium salt	3.9	18.6	3.9
0.0	2.37	2,2,3-TPA, sodium salt	4.5	21.8	5.5
0.0	1.94	TCA	2.2	20.8	9.2
0.0	1.70	Dalapon	2.2	22.7	9.1
0.0	2.11	2,2,3-TPA	2.2	22.9	6.3
0.5	0.0		6.6	13.7	8.7
0.5	0.69	MCA, sodium salt	5.1	12.1	7.4
0.5	1.10	TCA, sodium salt	7.8	9.7	7.0
0.5	0.98	Dalapon, sodium salt	5.6	11.6	6.1
0.5	1.19	2,2,3-TPA, sodium salt	6.1	11.9	7.3
0.5	0.97	TCA	3.2	11.6	7.9
0.5	0.85	Dalapon	3.4	12.6	6.8
0.5	1.06	2,2,3-TPA	3.2	16.6	9.0
1.0	0.0		6.6	5.6	6.2
1.0	1.39	MCA, sodium salt	5.1	4.8	7.5
1.0	2.21	TCA, sodium salt	7.8	4.6	5.7
1.0	1.96	Dalapon, sodium salt	5.6	4.6	1.8
1.0	2.37	2,2,3-TPA, sodium salt	6.3	5.4	2.0
1.0	1.94	TCA	3.2	3.6	4.5
1.0	1.70	Dalapon	3.3	4.6	3.2
1.0	2.11	2,2,3-TPA	3.2	8.0	6.8
Untreated				21.7	11.5
LSD at the 5% level				4.3	2.4
LSD at the 1% level				5.6	3.2
CV	%			20	19

[a]Rates of ATA are in lb/A of active 3-amino-1,2,4-triazole. The chlorinated acetic and propionic compounds were added at equimolar amounts, and their rates are lb/A of acids or sodium salts.

[b]Fresh weights were recorded 1 month following treatment.

with ATA alone (Table 3). The carboxylic acids as additives to ATA solutions were just as effective as the sodium salt of dalapon on barley.

The addition of the carboxylic acids to the ATA solutions had little or no effect on the chlorosis developing in the treated primary leaves of beans. The percent chlorosis in the growth above the primary leaves was increased, but the carboxylic acids were less effective than the sodium salt of dalapon in this respect. ATA alone reduced the weight of growth above the primary leaves of kidney beans; addition of equimolar amounts of the acids to ATA solutions caused a further weight reduction (Table 3). All the acids were effective, but the sodium salt of dalapon as an additive produced the greatest weight reduction. It must be pointed out, however, that the sodium salt of dalapon alone reduced weights as much as ATA alone.

Studies on herbicidal synergism. The results are presented graphically for mixtures of ATA and the sodium salt of dalapon on barley, kidney beans and barnyard grass in Figure 1 and for mixtures of ATA with monuron on the same plants in Figure 2. These data show

Table 3. The response of barley and kidney beans to mixtures of ATA and the unsubstituted carboxylic acids.

Application rate—lb/A[a]			pH of spray solutions	Fresh weights in gms.[b]	
ATA	Acid			Barley	Kidney beans
0.0	0.71	Acetic	2.4	8.7	11.1
0.0	0.88	Propionic	2.4	8.8	9.7
0.0	1.05	Butyric	2.4	8.0	11.9
0.0	1.22	Valeric	2.4	8.0	10.0
0.0	1.38	Caproic	2.4	8.6	10.2
0.0	1.55	Heptanoic	2.6	7.1	10.2
0.0	1.96	Dalapon, sodium salt	3.6	6.6	6.2
1.0	0.0		6.6	4.2	7.4
1.0	0.71	Acetic	3.9	2.6	4.4
1.0	0.88	Propionic	3.9	2.5	4.2
1.0	1.05	Butyric	3.9	3.3	3.7
1.0	1.22	Valeric	3.9	1.9	4.1
1.0	1.38	Caproic	4.1	2.5	4.2
1.0	1.55	Heptanoic	4.1	1.7	4.1
1.0	1.96	Dalapon, sodium salt	6.0	2.7	2.2
Untreated				7.3	11.1
LSD at the 5% level				1.0	2.3
LSD at the 1% level				1.3	3.1
CV		%		9	28

[a]Rates of ATA are in lb/A of active 3-amino-1,2,4-triazole. The acids in the mixtures were equal in molarity to the ATA.
[b]Fresh weights were determined 3 weeks after treatment.

that mixtures of ATA and the sodium salt of dalapon were never more than additive and in some cases the effects were less than additive, e.g. ATA plus the sodium salt of dalapon on barnyard grass (Figure 1).

Mixtures of ATA and monuron were approximately additive on barnyard grass, but on kidney beans and barley these mixtures were

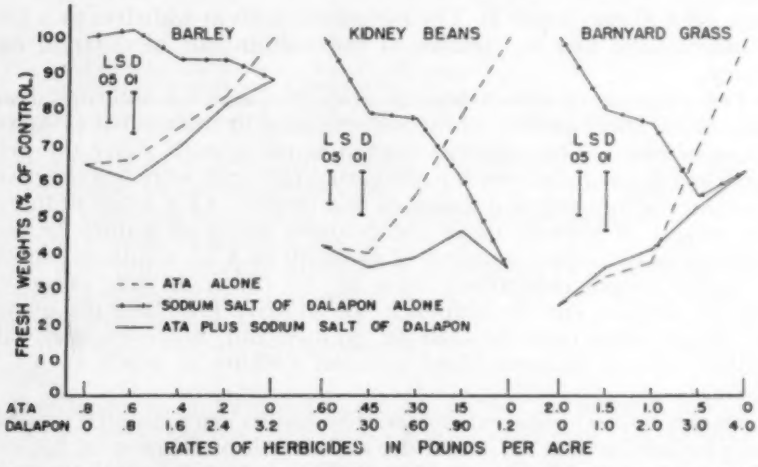

Figure 1. The response of barley, kidney beans and barnyard grass to several rates of ATA and the sodium salt of dalapon alone and in combination.

somewhat more than additive (Figure 2). Quite marked reductions in fresh weights of kidney beans and barley were produced by certain mixtures. The most effective mixtures in this respect were those containing the middle rate of ATA and monuron and those containing the low rate of monuron with the second highest rate of ATA.

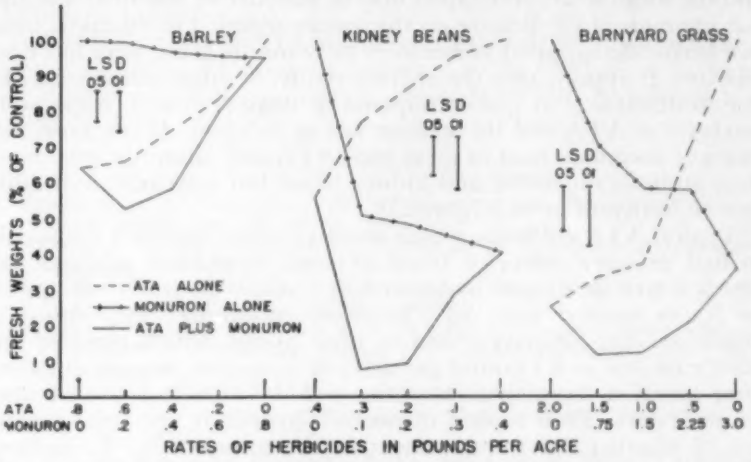

Figure 2. The response of barley, kidney beans, and barnyard grass to several rates of ATA and monuron alone and in combination.

The response data of Bermuda grass to foliage sprays of ATA and the sodium salt of dalapon alone and in mixtures are not reported. Fresh weights of top growth were determined 5 weeks after treatment; there were three subsequent harvests, all spaced 5 weeks. Dalapon, as the sodium salt, alone reduced the fresh weight of Bermuda grass much more at the initial harvest than ATA at the same rate (6 lb/A). In mixtures ATA did not appear to add or subtract from the phytotoxicity of the dalapon derivative. Six pounds per acre of the sodium salt of dalapon retarded regrowth of Bermuda grass more than the same rate of ATA. Two of the mixtures were less effective in suppressing regrowth than either herbicide alone. With this species the effects of ATA and the sodium salt of dalapon were less than additive.

DISCUSSION

The sodium salt of dalapon alone reduced the fresh weights of barley and kidney beans whereas the carboxylic acids alone had no apparent effect on weights (Table 3). Additions of equimolar amounts of several carboxylic acids to ATA solutions produced reductions of the weights of barley and kidney beans in addition to the reduction caused by ATA alone. The mixtures of ATA and the acids were just as effective on barley as mixtures of ATA and the sodium salt of dalapon. Since the carboxylic acids apparently have no herbicidal activity, particularly at the rates used in this

test, it is suggested that penetration and/or translocation of ATA was increased by inclusion of the acids in the herbicidal solutions. The pH of the sprays may be involved, particularly if the greater activity was due to increased penetration.

The data in Table 1 and Figure 1 indicate that the effects of ATA and the sodium salt of dalapon may be additive or less than additive but not more than additive on the species tested. The effects of these two herbicides, applied as mixtures to Bermuda grass, were less than additive. It appears that the varying results of other workers may be due to differences in species response or stage of growth response to mixtures of ATA and the sodium salt of dalapon. At the rates and ratios of chemicals used in these tests, ATA and monuron were more than additive on barley and kidney beans but approximately additive on barnyard grass (Figure 2).

Typical ATA chlorosis, which usually can be seen after 8 hours in treated primary leaves of beans exposed to normal sunlight and which is well developed by the end of 2 sunny days, did not appear on leaves sprayed with ATA solution containing any amount of monuron. The primary leaves of bean plants, which received any dosage (as low as 0.1 pound per acre) of monuron, became chlorotic after about 4 days, then necrotic, and defoliation followed after about 7 days. Thus typical monuron phytoxicity appeared regardless of whether ATA was present in the solution. ATA—induced chlorosis was reduced in the primary leaves of beans treated with certain solutions of ATA and the sodium salt of dalapon (Table 1). Therefore the reaction(s) of ATA within the leaf which leads to development of chlorosis appeared to be blocked when monuron or the sodium salt of dalapon was applied with the ATA. The dalapon derivative was required in at least equimolar amounts with ATA for this effect to be observable (Table 1), but this does not preclude the possibility that some effect occurred at lower concentrations. Equimolarity of monuron in the solution was not necessary.

SUMMARY

A series of tests were conducted to determine the response of kidney beans, barley, and barnyard grass to mixtures of ATA with several chlorinated carboxylic acids and salts of the acids, to mixtures of ATA with unsubstituted carboxylic acids, and to mixtures of ATA and monuron. The response of Bermuda grass to mixtures of ATA and the sodium salt of dalapon was also investigated. The results may be summarized as follows:

1. Marked reductions in fresh weights of seedling barley and kidney beans were produced by several mixtures of ATA and the sodium salt of dalapon. Combinations of ATA and certain chlorinated acids, or sodium salts of chlorinated acids, produced results similar to those caused by combinations of ATA and the sodium salt of dalapon.

2. ATA solutions containing equimolar amounts of several carboxylic acids reduced the fresh weights of barley and kidney beans more than ATA solutions without the acids. Mixtures of ATA and

the acids were just as effective on barley as mixtures of ATA and the sodium salt of dalapon.

3. The effects of ATA and the sodium salt of dalapon were either additive or less than additive on the species studied in these tests. At the rates and ratios of chemicals used, ATA and monuron were more than additive on barley and kidney beans but approximately additive on barnyard grass.

4. The reaction(s) of ATA within the leaf which leads to development of typical ATA-chlorosis appeared to be blocked or in some way eliminated when monuron or the sodium salt of dalapon was applied with the ATA.

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Chemical Weed Control in Seedling Alfalfa. I. Control of Weedy Grasses[1]

M. K. McCarty and Paul F. Sand[2]

Establishment of new seedings of alfalfa is often difficult because of the many hazards encountered during the first season of growth. In the Central Great Plains moisture is often the major factor determining the degree of success of the operation. This condition can be accentuated by the presence of a population of annual grasses such as the foxtails (*Setaria* spp.) and barnyard grass (*Echinochloa crusgalli* L. Beauv.). These grasses have a more rapid seedling growth rate than alfalfa and tend to produce a drouthy condition in the soil by rapid utilization of the available moisture. The same effect often results from the use of oats or other small grains as companion crops.

Review of Literature

Alfalfa seed germinates rapidly but the seedlings become established slowly in comparison with some of the weedy grasses. Stapledon et al. (9) found that seed of high viability is not enough to insure high seedling establishment. Their experiments showed that the average establishment of viable seeds for all grasses tested was 39.3 percent and for the clover species 52.3 percent. Therefore, it is not only important to have a well prepared seedbed but weed competition should also be held to a minimum when establishing legume seedlings.

Blaser et al. (2) stated that when different forage species are seeded together a struggle for survival develops immediately after the first seeds germinate. They seeded birdsfoot trefoil, which has slow seedling development, with Kentucky bluegrass, also a slow developer, and with a light rate of orchard grass which has a much more rapid seedling development. The relative yield of birdsfoot trefoil the following year was 47 when seeded with the orchard grass compared to 100 when seeded with the Kentucky bluegrass. When trefoil was seeded with a complex mixture of aggressive species (alfalfa, orchard grass, red clover, and ladino clover) the relative yield was only 10. With this complex mixture, the aggressive species reduced the stand and yield of trefoil even though seeding rates were adjusted. This is sometimes the case if a heavy stand of annual weedy grasses compete with a seedling stand of alfalfa. There have been instances where stands of seedling alfalfa were reduced sufficiently due to competition from foxtail that reseeding was necessary the following year.

Annual weedy grasses have been controlled successfully in alfalfa by treating with TCA and dalapon. In 1953, Klingman (5) obtained

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good control of weedy grasses by applying TCA about 6 weeks after planting alfalfa. He reported similar results using both dalapon and TCA in 1954 (6). The number of alfalfa plants per square foot was higher where good grass control was obtained. Bondarenko and Slife (3) treated alfalfa when it was 3 inches tall with dalapon at 2, 4, and 6 lb per acre and TCA at 3, 6, and 9 lb per acre. Neither chemical had a permanent effect on the alfalfa. The higher rates of both chemicals gave excellent control of foxtail and some reduction in stand of pigweed.

In 1955, Slife (8) reported that applications of TCA at 4 and 8 lb and dalapon at 2 and 4 lb per acre at three stages of growth of alfalfa, pre-emergence, 1 to 2 inch and 5 to 6 inch stages, gave good control of weedy grasses. Dalapon at 4 lb per acre was the most effective post-emergence treatment. Alfalfa seedlings were retarded by the higher rates of the chemicals but later recovered. Elder (4) reported excellent control of annual grasses by application of TCA and dalapon to alfalfa when it was 2 to 4 inches and 6 to 12 inches tall. However, a few alfalfa plants were killed when the chemicals were applied at the 2 to 4 inch stage but were uninjured by the later application.

Santelman et al. (7) found that TCA and dalapon applied at three stages of growth to a new seeding of alfalfa gave moderate to severe injury to the alfalfa. These chemicals gave fair to good control of wheat and oats seeded with the legumes but had little effect on other weeds. They indicated that DNBP appeared to be the most promising chemical for weed control in legume seedings.

Materials and Methods

Three contiguous sets of plots were laid out on Sharpsburg silty clay loam on the Agronomy Farm of the Nebraska Agricultural Experiment Station for this study. The area had been limed in 1953 and 40 pounds of P_2O_5 was applied at seeding time. The dates of seeding on the three areas were April 23, 1954, April 16, 1955, and April 18, 1956. Ten pounds per acre of Ranger alfalfa seed was used with an addition of 10 per cent by weight of weed seed, primarily green and yellow foxtails *(Setaria spp.)*.

A split-plot design with four replications was used each year. The main plots were dates or stages of growth and sub-plots were chemical treatments. Sub-plot size was 7 by 21 feet.

Two chemicals were used in 1954, the sodium salts of trichloroacetic acid (TCA) and 2,2–dichloropropionic acid (dalapon). The sodium salt of 2,2,3–trichloropropionic acid (2,2,3–TPA) was used in addition to these in 1955 and 1956. Rates used were TCA at 5 and 7 lb per acre and dalapon and 2,2,3–TPA at 1, 2 and 4 lb per acre (active ingredient). All applications were made as aqueous sprays at 40 gpa. A portable sprayer was used that utilized a carbon dioxide bottle with a two-stage pressure regulator to maintain a constant pressure of 38 psi.

The herbicide applications were made at three stages of growth,

namely; emergence, 1 week after emergence and 4 weeks after emergence of the alfalfa. Alfalfa emergence was not uniform, consequently at the first treatment date some seedlings were just emerging while others had the unifoliolate leaf. A partial stand of grass seedlings was evident by this time. One week later, at the 1 week after emergence stage, the alfalfa had 2 to 3 trifoliolate leaves and was about 1 inch tall. The weedy grasses had 1 to 2 leaves and were from ½ to 1 inch tall. Three weeks later, at the 4 weeks after emergence stage, the alfalfa had 6 to 8 leaves and was 3 to 4 inches tall. The grass was 3 to 5 inches tall with 5 to 7 leaves. Some green foxtail was in the boot stage.

Evaluation of treatment effects was made by making counts of grass plants and alfalfa stems in five 2 x 4 foot quadrats per plot (alfalfa plant counts in 1954). This is the equivalent of 60 lineal feet of drill row. These counts were made during the last week in June and the first week in July each year.

One 2 x 4 foot quadrat per plot was clipped at the soil surface in early July when the alfalfa was in the early bud stage. The plant material was separated by hand into three components; alfalfa, grasses, and broad-leaved weeds. This material was oven-dried, weighed and converted to a pounds per acre basis.

Results and Discussion

The area used in this study had been kept relatively free of weeds for several years by normal methods of row crop culture. However, a fairly uniform stand of weedy grasses, primarily green and yellow foxtails, was associated with the alfalfa seedlings as a results of planting weedy grass seed with the alfalfa seed. Table 1 gives counts of grass plants in late June each year indicating check populations and the influence of the various chemical treatment on plant numbers.

In making the counts, all live grass plants were included. This did not give as clear a picture of the effectiveness of the treatment as was desired because many of the plants whose growth had been

Table 1. Number of grass plants in 40 square feet in late June as affected by chemical treatment at three stages of growth of the alfalfa.

Treatment	Rate lb/A	Emergence			1 week after emergence			4 weeks after emergence		
		1954	1955	1956	1954	1955	1956	1954	1955	1956
Check	–	271	424	252	262	422	296	321	418	217
TCA	5	54**	166**	166*	33**	226**	86**	101**	360	209
	7	26**	112**	106**	19**	156**	63**	127**	423	186
Dalapon	1	122**	280**	155*	124**	416	142**	140**	402	190
	2	98**	185**	188	87**	206**	83**	205**	420	168
	4	94**	112**	134**	73**	117**	50**	166**	431	188
2,2,3-TPA	1	—	348	214	—	296*	187*	—	376	162
	2	—	244**	187	—	247**	106**	—	296*	197
	4	—	183**	144**	—	200**	74**	—	324	201
Standard error of mean difference		38	50	37	38	50	37	38	50	37

*Difference from check exceeds 5 pct. level of significance.
**Difference from check exceeds 1 pct. level of significance.

inhibited by the chemicals were still green enough to be included in the count. At the emergence treatment date many of the grass plants were in a 1 to 2 leaf stage of development and being more highly susceptible to treatment effect, died quickly. They were either brown or partially disintegrated by counting time. The same holds true at the 1 week after emergence treatment date when the grasses were at the 2 to 3 leaf stage of development. By the 4 weeks after emergence treatment date the grasses were approaching full size with some of the green foxtail plants in the early boot stage. They were not only less susceptible to the chemicals at this stage, but following treatment, the more mature tissues deteriorated less quickly and there was a shorter time interval between treatment and counting of the weeds.

The TCA was highly effective at both the earlier dates with some reduction in effectiveness at the 4 weeks after emergence stage. Dalapon, which has its major effect from foliage application, was slightly more effective at the 1 week after emergence stage when a greater percentage of the grass seedlings had emerged. Count numbers and visual observations indicated that dalapon was more effective than 2,2,3–TPA on an equal rate basis.

A more quantitative evaluation of the effectiveness of the herbicide treatment was made by clipping quadrats from each plot, separating the grass, alfalfa and broad-leaved weed components and computing pounds of dry matter per acre. The data for the weedy grasses are given in Table 2. Here the relative value of treatments

Table 2. Yield of weedy grasses harvested early in July as affected by chemical treatment at three stages of growth of the alfalfa.

Treatment	Rate lb/A	Pounds oven-dry matter per acre								
		Emergence			1 week after emergence			4 weeks after emergence		
		1955	1956	Av.	1955	1956	Av.	1955	1956	Av.
Check	–	1196	1041	1118	1422	981	1202	1374	714	1044
TCA	5	126**	39**	82	192**	15**	104	423**	78**	250
	7	45**	27**	36	42**	27**	34	480**	33**	256
Dalapon	1	471**	102**	286	288**	129**	208	840*	78**	459
	2	96**	60**	78	48**	15**	32	522**	81**	302
	4	102**	18**	60	8**	6**	7	486**	39**	262
2,2,3-TPA	1	954	1035	994	654**	834	744	921	129**	556
	2	435**	297**	366	375**	234**	304	936	74**	505
	4	447**	117**	282	105**	66**	86	570**	27**	298
Average[a]		430	304	—	348	256		756	146	—
Standard error of mean difference		234	123		234	123	—	234	123	

*Difference from check exceeds 5 pct. level of significance.
**Difference from check exceeds 1 pct. level of significance.
[a]Standard error of mean difference for stages: 1955—112; 1956—46.

among kinds and rates of chemicals and between dates of application is more readily observed. The data obtained following both TCA and dalapon treatments indicate highly effective control of the weedy grasses at the two earlier dates of application. As an average, the 4 lb rate of 2,2,3–TPA was not as effective as the 2 lb rate of dalapon.

The averages of two years data (1955 and 1956) for the yields of the weedy grasses are given in multiple histogram form in Figure 1. Treatment averages across the 3 application dates show the 4 lb rate of dalapon and the 7 lb rate of TCA as the most effective treatments with 2 lb of dalapon and 5 lb of TCA following closely in that order. Although 1 lb of dalapon gave only about 70 per cent control, it had effectively reduced the competition, particularly at the two early stages. Figures 2 and 3 illustrate plot appearance for 5 and 7 lb of TCA and 1 and 2 lb of dalapon, respectively.

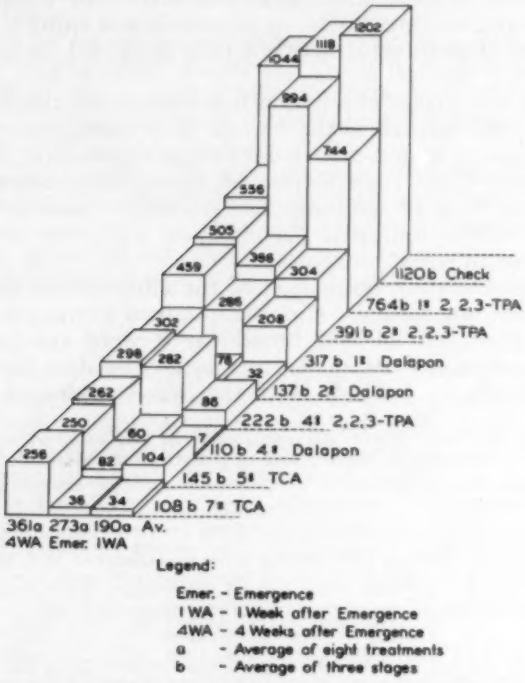

Figure 1. Yield of weedy grasses in pounds oven-dry matter per acre harvested early in July as affected by chemical treatment at three stages of growth of the alfalfa. Each bar represents an average of four replications for 2 years.

Scrutiny of the above figures will reveal little or no damage to the alfalfa by the chemicals at the rates used. This was also borne out by the plant counts shown in Table 3. It should be noted that the 1954 counts were on a plant basis rather than on a stem count basis. However, it is felt that the stands were closely comparable because excavation of several hundred plants in the spring of 1955 showed that stems numbered between 4 and 5 per plant by that time. No real differences among treatments or between treatments and check were evident at the time the counts were made.

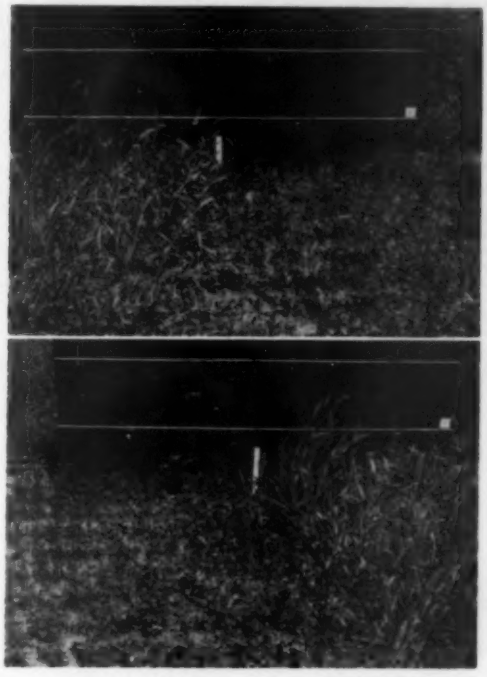

Figure 2. Weedy grass control in spring-seeded alfalfa. Upper photo; 5 lb TCA per acre on right and check on left. Lower photo; 7 lb TCA per acre on left and check on right. Excellent control had been achieved with the 5 lb rate with no damage to the alfalfa. Seven lb per acre gave complete control of the weedy grasses but resulted in minor stunting and some leaf and tip burn. Treatments made 1 week after emergence of the alfalfa. Photo July 9, 1956.

Table 3. Number of alfalfa stems in 40 square feet in late June as affected by chemical treatment for weedy grass control at three stages of growth.[a]

Treatment	Rate lb/A	Emergence			1 week after emergence			4 weeks after emergence		
		1954	1955	1956	1954	1955	1956	1954	1955	1956
Check		310	964	1024	283	854	999	316	1034	1071
TCA	5	289	1060	1032	269	1192	1090	350	958	1121
	7	267	1090	954	304	1182	1025	298	899	1056
Dalapon	1	307	968	895	326	1194	886	351	960	1005
	2	311	1052	1102	312	1136	951	317	1120	1116
	4	228	824	966	257	1244	1078	380	1098	1037
2,2,3-TPA	1	—	950	954	—	1156	849	—	991	872
	2	—	1277	999	—	1236	1027	—	1005	1020
	4	—	1068	916	—	1015	1061	—	1126	962
Standard error of mean difference		60	139	92	60	139	92	60	139	92

[a]Plant counts in 1954 instead of stem counts.

Figure 3. Weedy grass control in spring-seeded alfalfa. Upper photo; 1 lb dalapon per acre on left and check on right. Lower photo; 2 lb dalapon per acre on right and check on left. In this test where the weedy grasses were primarily green and yellow foxtail, dalapon at 1 lb gave effective reduction of the grasses. Two lb gave excellent control with only a few stunted plants left in the plot. No injury was observed on the alfalfa. Treatments made 1 week after emergence of the alfalfa. Photo July 9, 1956.

Alfalfa yields obtained from the early July clipping are given in Table 4. The treatment averages for the 2 years are shown in Figure 4. The two early dates of treatment averaged about 600 pounds of alfalfa per acre over all chemicals and rates while the late date averaged 537 pounds per acre. This reflects two types of influence: (1) reduced competition to the alfalfa by control of the grass at a young stage of growth, and (2) the small amount of damage sustained by the alfalfa was most evident at the 4 weeks after emergence treatment date. The 4 lb rate of dalapon resulted in some stunting of the alfalfa and the 7 lb rate of TCA gave some leaf and growing point burn. These effects were observed only on the first growth as there was no evidence of injury due to chemical on the regrowth following mowing of the plots in July.

Treatment averages across application dates show the 2 lb rate of

Table 4. Yield of alfalfa harvested at bud stage (early in July) in the seeding year as affected by chemical treatment for weedy grass control at three stages of growth.

Treatment	Rate lb/A	Pounds oven-dry matter per acre								
		Emergence			1 week after emergence			4 weeks after emergence		
		1955	1956	Av.	1955	1956	Av.	1955	1956	Av.
Check	–	453	528	490	507	441	474	609	447	528
TCA	5	588	696	642	759	549	654	447	669	558
	7	543	714	628	759	504	632	444	528	486
Dalapon	1	591	546	568	654	582	618	402	480	441
	2	618	657	638	894	567	730	756	573	664
	4	468	516	492	528	474	501	390	534	462
2,2,3-TPA	1	582	555	568	705	573	639	564	492	528
	2	636	777	706	675	639	657	546	588	567
	4	609	597	558	330	501	416	699	483	591
Standard error of mean difference		153	109		153	109		153	109	

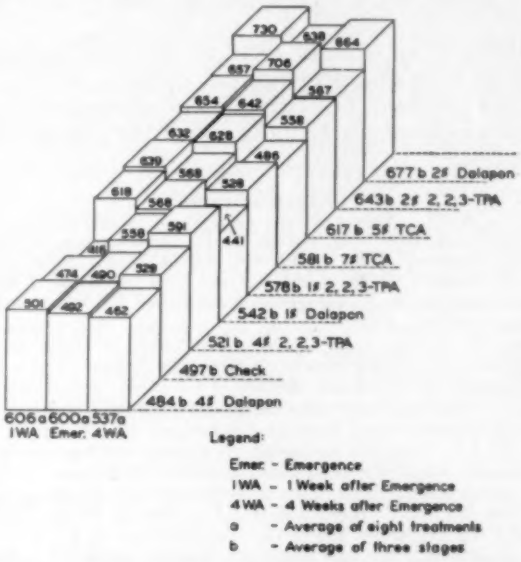

Figure 4. Yield of alfalfa in pounds oven-dry matter per acre harvested early in July as affected by chemical treatment for grass weed control at three stages of growth of the alfalfa. Each bar represents an average of four replications for 2 years.

dalapon with the largest amount of alfalfa produced followed by 2 lb of 2,2,3–TPA and 5 lb of TCA. The check plots and those treated with 4 lb of dalapon produced essentially the same amount of alfalfa. The advantage gained by the complete elimination of the weedy grasses with this rate of dalapon was offset by the slight stunting effect on the alfalfa. This was not too serious as the alfalfa fully recovered following mowing.

Neither stand nor yield of broad-leaved weeds was significantly reduced by any of the chemicals at the rates and dates used. Some stunting and reduction of flowering was observed in the smartweed with the heavier rates of dalapon and TCA at the later dates of application.

SUMMARY

Three years of testing with TCA and dalapon and 2 years with 2,2,3–TPA indicated that these chemicals show much promise for the control of weedy grasses in seedling Ranger alfalfa. TCA at 5 to 7 lb per acre and dalapon at 1 to 2 lb per acre gave very good results in all 3 years when applied 1 week after emergence of the alfalfa.

The 2,2,3–TPA material appeared to be somewhat less active in these tests, requiring about twice as heavy a rate of application as dalapon to achieve comparable results.

Dalapon at 4 lb per acre and TCA at 7 lb per acre gave evidence of temporary injury to the alfalfa, but resulted in little or no stand reduction.

As the alfalfa is apparently tolerant of these chemicals at the rates used from time of emergence on, there is no reason to delay application to a late date. The reduction of competition to the alfalfa seedlings becomes more effective the earlier the growth of the weedy grasses is stopped.

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The Influence of Soil Factors on the Phytotoxicity and Plant Selectivity of Diuron[1]

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ALTHOUGH many studies have been made on the behavior of herbicides in soils, there is still insufficient information to make intelligent use of many herbicides. Certain theories on herbicidal behavior in soils are well established in some regions, but the applicability of such theories to other regions under different soil and environmental conditions is not always known.

The intensive investigation of the usefulness of pre-emergence applications of herbicides, beginning about 1948, has revealed some outstanding successes and some erratic results (3). Some of the causes of non-uniform results have been studied. Considerable attention has been devoted to evaluating the importance of herbicide vapors, micro-leaching,[3] and moderate timely rainfall to the success of pre-emergence type applications (4, 5, 6). In many cases, erratic results have been ascribed to variation from one soil type to another (3, 11). Organic matter and clay content frequently have been assigned major roles although the experiments often were not designed to yield such information. The question of variation in the selective control of plants by chemicals from soil to soil often has been raised, but scant information is available on this point (3, 8).

The experiments described herein were designed to determine the effect of soil-to-soil variation in North Carolina on herbicidal phytotoxicity and selectivity for plants and to assign, if possible, the variability to specific soil factors. In order to evaluate the role of soil factors most easily, the procedure of mixing the herbicide thoroughly with the soil has been followed. Diuron [3–(3,4–dichlorophenyl)–1,1–dimethylurea] was used in this study.

EXPERIMENTAL PROCEDURE

The 12 soils used in this study along with their chemical and physical properties and their abbreviated designations are listed in Tables 1 and 2.[4] These soils were selected for their diverse properties, acreage represented, and their agricultural importance in the Southeastern United States. They were collected from areas in agricultural use except for White Store sandy loam soil (WS) which was

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[3]Micro-leaching is taken to mean the movement of herbicide into the area of the weed and crop seeds (1/8 to 2 inches deep). Macro-leaching would be leaching of herbicide to depths greater than 2 inches.

[4]Appreciation is expressed to Mr. C. D. Welch of the North Carolina State Department of Agriculture for making the chemical analyses and to Dr. S. B. McCaleb, formerly with the North Carolina Agricultural Experiment Station, under whose direction the physical analyses were made.

taken from a wooded area. Approximately 1 ton of soil was collected from the upper 4 inches of each soil site, passed through a 16-mesh screen, thoroughly mixed, and stored in steel drums with tight covers until used.

Table 1. Chemical and physical properties of twelve soils used in Experiments I and II.

Soil type	Soil code name	Cation exchange capacity (me.eq./100 g)	Organic matter %	Clay (% < .002 mm)	Surface area—(cm^2/g)	Exchangeable bases (me.eq./100 g)			Soluble P ppm	pH
						Ca	Mg	K		
White Store sandy loam	WS	4.35	1.9	6.6	1050	0.9	0.9	0.10	6	5.1
Georgeville silt loam	G	6.10	1.9	22.3	3120	0.8	0.7	0.19	8	5.4
Iredell sandy loam	I	8.90	2.6	10.9	1529	4.2	2.2	0.10	13	5.8
Cecil sandy loam	CSL	6.20	3.1	13.7	1813	4.2	2.1	0.43	78	6.0
Cecil sandy clay loam	CSCL	7.35	3.4	20.8	2606	4.4	1.8	0.68	70	6.2
Cecil clay loam	CCL	8.25	2.8	48.4	5666	4.5	2.9	0.67	17	6.1
Norfolk loamy sand	N	1.95	0.8	2.3	525	0.3	0.5	0.10	84	5.8
Lakeland sand	LK	4.90	2.3	2.8	458	1.3	1.1	0.19	64	5.5
Lynchburg sandy loam	LY	5.60	3.0	5.7	1084	1.0	0.8	0.17	26	4.8
Craven sandy loam	CR	3.65	2.1	7.6	1236	0.9	0.6	0.29	49	5.2
Coxville silt loam	CX	6.10	3.2	7.8	1442	1.0	0.6	0.31	40	4.7
Bladen loam	B	17.75	5.0	16.6	2215	7.7	2.0	0.43	43	5.2

Table 2. Types of colloids found in twelve soils used in Experiments I and II.[a]

Soil code name	Soil colloid								
	Kaolinite	Montmorrillonite	Vermiculite	Hydrous mica	Illite	Quartz	Gibbsite	Halloysite	Goethite
WS	R	r	r	—	r	r	—	—	—
G	R,D	—	R,D	—	—	—	r,d	—	—
I[b]	R	R	r	—	—	—	r,d	—	—
CSL[c]	R,D	—	—	r	—	—	d	—	—
CSCL	R,D	—	r	—	—	—	r,d	—	—
CCL	R,D	—	r	—	—	—	r,d	—	—
N	R,D	—	—	—	r	R,D	—	—	—
LK[d]	r,d	r,d	d	—	r,d	—	—	—	—
LY[e]	R,D	d	R	—	r	r	—	r,d	—
CR	R	D[e]	R,d	—	r	r	r	—	r
CX[e]	R,D	R,d	R,d[f]	—	r	—	—	—	—
B[e]	R,d	r,d[f]	—	—	—	r	—	—	—

[a]R indicates a major component and r a minor component as revealed by X-ray analysis. D indicates a major component and d a minor component as measured by differential thermal analysis.
[b]Silt fraction was predominately kaolinite and quartz.
[c]Diffuse X-ray patterns obtained.
[d]Both differential thermal and X-ray analysis gave poor patterns. The silt fraction was predominately kaolinite.
[e]Poor pattern—generally diffuse.
[f]Montmorillonite or vermiculite.

Cotton and Italian rye grass plants were grown in slightly less than 1 quart volumes of soil. The exact amount of soil used was the amount required to fill 4 inch diameter, 1 quart cans to within ¾ of

an inch of the top. These amounts for the 12 soil types are shown in Table 3. The diuron required for each can of soil was added to a 60 ml aqueous suspension and thoroughly mixed with the soil by hand. Diuron rates of 0, ½, 1, 2, 3, 4, and 6 ppm (oven-dry, soil-weight basis) were used for cotton and 0, ¼, ½, ¾, 1, 1½, and 2 ppm for Italian rye grass. The amount of herbicide used per can of soil may be calculated from Table 3. After mixing with herbicide, the portions of soil were transferred to the uniform weight, 1 quart containers. Six acid-delinted, ceresan-treated Coker 100 Wilt cotton seeds were planted 1 inch deep in cans designated for cotton. Thirty-five Italian rye grass seeds were planted ¼ inch deep in cans designated for grass.

Table 3. Soil moisture constants and soil weights used in Experiments I and II.

Soil code name	Soil moisture equivalent—%	Soil free drainage value—%	Maximum available soil moisture—%	Grams oven-dry soil per can
WS	13.7	27.5	20.6	1239
G	23.5	41.0	29.3	1010
I	15.8	33.0	24.4	1180
CSL	14.1	31.0	22.6	1140
CSCL	15.8	30.0	22.9	1244
CCL	25.1	45.5	31.9	963
N	5.4	18.9	12.2	1377
LK	6.7	31.0	18.9	1198
LY	14.8	22.5	17.7	1232
CR	10.9	24.5	17.7	1281
CX	19.2	22.7	21.0	1112
B	20.1	42.8	31.4	981

Immediately after planting, all treatments were surface watered to the maximum level of "available" soil moisture. The maximum amount of available moisture for these studies was assumed to be that value which was half way between the moisture equivalent (7) and the free drainage value, except for Georgeville silt loam (G) and Cecil clay loam (CCL) soils in which cases the one-third way point was taken. The free drainage value was established by determining the equilibrium moisture content when 1 quart cans of soil were saturated with water and allowed to drain for 140 hours through five ⅛ inch diameter holes in the bottom of each can. The moisture equivalents, free drainage values and maximum amounts of available moisture for each soil are shown in Table 3. Each can was weighed and surface watered every third day during the first half of each experiment and every second day during the last half of each experiment to bring the moisture content up to the maximum available amount. There were no holes in the bottom of the cans and thus no drainage was allowed. This system of watering was found to give excellent plant growth.

The cotton plants were thinned to one plant per can, as in previous experiments (12). The grass plants were not thinned and 25 to 30 plants became established in each can.

Experiment I involved six soils formed from residual materials found in the Piedmont area of North Carolina and Experiment II involved six soils formed from marine-deposited material found in

the Coastal Plains area of North Carolina. Experiment I was conducted in the greenhouse in September and October of 1954, while Experiment II was conducted in the greenhouse in March and April of 1955. Air temperatures were maintained between 75 and 95° F. For the most part, temperatures ranged between 78 and 88° F. Damping-off organisms were combated as in previous experiments (12).

Experiments I and II were terminated 5 and 6 weeks, respectively, after planting. Treatments were watered within 12 hours of harvest. At the conclusion of the experiment dry shoot weights were recorded. Randomized block designs were used with five replications for Experiment I and six for Experiment II. In all cases, each of the five or six replications included two of the untreated or check treatments in order to produce a better reference point than would be available with a single check. As a result, two least significant difference (LSD) values are used with the data, one for comparing the check with other treatments and one for use among the other treatments. Where zero yields were obtained for all replications for a given herbicide rate on a given soil, they were omitted from the analysis of variance with a corresponding reduction in degrees of freedom.

Throughout this paper the amount of chemical required to produce a given effect on growth has been designated by the capital letters "GR" followed by a subscript Arabic numeral. The subscript indicates the percentage effect which the amount of herbicide under consideration has on the plant compared to untreated plants. The aspect of growth involved is indicated by lower case letters in parenthesis following the subscript, such as (dsw) which is taken to mean dry shoot weight. GR_{50}(dsw) would identify the amount of chemical producing a 50 percent reduction in dry shoot weight. The GR_{20}(dsw) and GR_{80}(dsw) values presented in Table 6 were estimated visually from eye-fitted curves using treatment means in the plotting. Separate GR_{50}(dsw) values were similarly estimated for each replication and the resultant values used to calculate the LSD and CV (coefficient of variability) values presented in Table 6. The GR_{50}(dsw) values presented in Table 6 were estimated by curvilinear regression methods using the treatment means presented in Tables 4 and 5.

Because of the critical importance of soil properties to the results of this work, a sketch of the techniques used to determine the soil properties is presented here. Cation exchange capacity was determined by extracting adsorbed ammonium from an ammonium acetate leached soil using an acidified sodium chloride solution. The ammonium obtained was distilled into a standard acid solution and determined by back titration. Organic matter was determined by oxidation with 0.4 N sodium dichromate and concentrated sulphuric acid. Dichromate reduction was determined by titration using ferrous ammonium sulphate. Surface area was calculated from the percentage of material found in each size class assuming spherical particles, a density of 2.65 and particle diameter equal to the average of the size class extremes. In determination of exchangeable bases, a

solution of Ca, Mg and K was obtained by leaching with neutral ammonium acetate. K was determined directly by the flame photometer. Ca was determined by the flame photometer after addition of lithium nitrate. Mg was prepared by evaporating a leachate sample to dryness, dissolving the residue in a dilute hydrochloric-sulphuric acid mixture and adding: (1) a solution of calcium chloride dihydrate, hydroxylamine hydrochloride and aluminum chloride hexahydrate, (2) a solution of sodium polyacrylate and thiazol yellow and (3) sodium hydroxide. The resultant color was read on a Cenco photelometer. Soluble phosphorus was determined by extraction with dilute hydrochloric-sulphuric acid mixture in the presence of charcoal. A 1 to 4 soil:solution ratio and a 5 minute shaking period were used. Ammonium molybdate-ammonium vanadate solution was used to extract and the resultant color was read on a Cenco photelometer. The soil pH was determined by glass electrode using a 1 to 1 soil:water ratio.

RESULTS AND DISCUSSION

The effect of diuron on the dry shoot weight of cotton and Italian rye grass grown on 12 soil types is shown in Tables 4 and 5. Separate LSD and coefficient of variability (CV) values have been calculated for each of the soil types and entered in the tables with the basic data.[5] The data presented in Tables 4 and 5 show that the 15 soils

Table 4. The effect of diuron on dry shoot weight of cotton and Italian rye grass grown on six residual soils. Experiment I.

Herbicide rate—ppm	Soil type					
	WS	G	I	CSL	CSCL	CCL
	Cotton—g/plant					
0	0.73	0.43	0.65	1.46	1.37	0.85
½	0.69	0.43	0.66	1.43	1.74	0.81
1	0.75	0.48	0.72	1.39	1.67	0.75
2	0.59	0.40	0.53	1.55	1.34	0.76
3	0.23	0.26	0.25	1.10	1.21	0.48
4	0.03	0.18	0.06	0.47	1.01	0.27
6	0.00	0.00	0.03	0.08	0.18	0.03
LSD						
O vs Tr. 5%	0.09	0.06	0.11	0.02	0.27	0.18
1%	0.12	0.08	0.15	0.03	0.37	0.25
Tr. 5%	0.10	0.07	0.13	0.03	0.31	0.21
1%	0.14	0.09	0.17	0.04	0.43	0.29
CV %	17	13	23	18	19	27
	Italian rye grass—g/plot					
0	0.66	0.27	0.66	1.81	1.70	0.94
¼	0.55	0.26	0.48	1.48	1.58	0.84
½	0.11	0.04	0.07	1.01	1.12	0.46
¾	0.01	0.01	0.00	0.15	0.31	0.22
1	0.00	0.00	0.00	0.02	0.07	0.10
1½	0.00	0.00	0.00	0.00	0.02	0.03
2	0.00	0.00	0.00	0.00	0.01	0.02
LSD						
O vs Tr. 5%	0.04	0.02	0.08	0.12	0.09	0.10
1%	0.06	0.03	0.11	0.17	0.12	0.14
Tr. 5%	0.05	0.02	0.09	0.14	0.10	0.12
1%	0.07	0.03	0.12	0.19	0.14	0.16
CV %	10	10	22	12	10	20

[5]Statistical analyses were made under the direction of Dr. D. D. Mason, North Carolina State College, Department of Experimental Statistics.

varied considerably in their productivity. The growth of Italian rye grass was found to be severely retarded by much lower amounts of diuron than were required to affect cotton.

Table 5. The effect of diuron on dry shoot weight of cotton and Italian rye grass grown on six marine soils. Experiment II.

Herbicide rate—ppm	Soil type					
	N	LK	LY	CR	CX	B
	Cotton—g/plant					
0	0.60	1.01	0.72	0.84	0.76	1.01
½	0.49	0.96	0.69	0.84	0.75	0.90
1	0.14	0.94	0.69	0.62	0.91	0.99
2	0.00	0.89	0.62	0.23	0.78	1.01
3	0.00	0.49	0.68	0.09	0.85	1.03
4	0.00	0.22	0.46	0.01	0.55	1.02
6	0.00	0.09	0.27	0.01	0.36	0.96
LSD						
O vs Tr. 5%	0.13	0.13	0.17	0.15	0.23	N.S.
1%	0.17	0.18	0.23	0.21	0.31	—
Tr. 5%	—	0.15	0.20	0.18	0.27	N.S.
1%	—	0.21	0.27	0.24	0.36	—
CV %	26	19	28	35	32	16
	Italian rye grass—g/plot					
0	0.67	1.05	0.47	0.82	0.58	1.17
¼	0.00	0.89	0.51	0.22	0.45	1.10
½	0.00	0.47	0.38	0.00	0.49	1.08
¾	0.00	0.02	0.20	0.00	0.34	1.04
1	0.00	0.00	0.05	0.00	0.17	0.98
1½	0.00	0.00	0.00	0.00	0.02	0.78
2	0.00	0.00	0.00	0.00	0.00	0.48
LSD						
O vs Tr. 5%	—	0.07	0.08	0.08	0.07	0.08
1%	—	0.10	0.11	0.11	0.09	0.11
Tr. 5%	—	0.08	0.09	0.09	0.08	0.10
1%	—	0.11	0.12	0.12	0.11	0.13
CV %	—	10	30	11	21	8

The effect of variation in soil properties on the toxicity of diuron to plants is best seen by inspection of the GR_{50}(dsw) values for cotton and Italian rye grass presented in Table 6. These values are the amounts of herbicide (ppm soil basis) required to give a 50 percent reduction in dry shoot yield. The most obvious difference revealed by the GR_{50}(dsw) values is that much greater variation was found in these values for the marine soils than for the residual soils. For the residual soils, only a two-fold factor existed between the lowest and highest GR_{50}(dsw) values; whereas, the comparable factor for the marine soils was ten-fold.[6] It is, therefore, apparent that some soil factor or factors exist which influence the toxicity of diuron to plants.

The properties of the soils presented in Tables 1 and 2 have been examined thoroughly in an attempt to reveal which soil factors are specifically involved in affecting diuron toxicity. The nine properties presented in Table 1 were analyzed statistically to determine the extent of their correlation among themselves and with the GR_{50}(dsw) values for cotton and Italian rye grass presented in Table 6. Corre-

[6]This comparison is made on the assumption that the same basic response of plants to diuron would be obtained under the environmental conditions used for Experiments I and II.

Table 6. The effect of soil type on selectivity and activity of diuron as shown by the rate (ppm) required to give specified reductions in dry shoot weight of cotton and Italian rye grass.

Soil code name	Diuron appl.—ppm				Ratio[a] cotton GR_{20}(dsw) ÷ grass GR_{80}(dsw)
	Grass GR_{20}(dsw)	Cotton GR_{80}(dsw)	Cotton GR_{20}(dsw)	Grass GR_{80}(dsw)	
	Experiment I				
WS	0.33	2.62	1.99	0.48	4.15
G	0.35	3.60	2.48	0.49	5.06
I	0.29	2.76	2.07	0.47	4.40
CSL	0.49	3.68	2.75	0.68	4.04
CSCL	0.61	4.64	2.88	0.75	3.84
CCL	0.54	3.35	2.48	0.77	3.22
LSD					
5%	0.07	0.60	—	—	—
1%	0.09	0.82	—	—	—
CV %	12	13	—	—	—
	Experiment II				
N	0.12	0.78	0.52	0.19	2.74
LK	0.44	3.01	2.38	0.66	3.61
LY	0.63	5.20	3.58	0.92	3.89
CR	0.17	1.62	0.91	0.32	2.48
CX	0.83	4.82	3.82	1.02	3.75
B	1.83	8.55	7.08	2.21	3.20
LSD					
5%	0.10	0.87	—	—	—
1%	0.14	1.21	—	—	—
CV%	10	20	—	—	—

[a]This ratio is a selectivity index indicating how many times the dosage required to give essential control of a grass (80% reduction) would be required to barely injure cotton (20% reduction).

lations for total bases (Ex. Ca + Ex. Mg + Ex. K) and for percent base saturation (total bases ÷ C.E.C.) × (100) were also calculated. The correlations obtained are presented in Table 7. From the 11

Table 7. The correlation of eleven soil properties among themselves and with diuron GR_{50}(dsw) values for cotton and Italian rye grass using twelve soil types.

Factors correlated	Cation exchange capacity	Organic matter	Clay content	Surface area	Exchangeable cations			Sol. P	pH	Total exchangeable bases	Percent base saturation
					Ca	Mg	K				
GR_{50}(dsw) cotton	0.85	0.93	0.19	0.21	0.07	0.30	0.00	−0.11	−0.28	0.58	0.02
GR_{50}(dsw) grass	0.89	0.90	0.17	0.18	0.07	0.30	0.00	−0.01	−0.26	0.61	0.02
Cation exchange capacity	—	0.87	0.36	0.36	0.09	0.58	0.00	−0.19	0.01	0.82	0.22
Organic matter	—	—	0.27	0.27	0.08	0.51	0.01	−0.02	−0.10	0.75	0.30
Clay content	—	—	—	1.00	0.05	0.69	0.01	−0.32	0.50	0.58	0.52
Surface area	—	—	—	—	0.05	0.65	0.01	−0.36	0.44	0.55	0.46
Exchangeable Ca	—	—	—	—	—	0.08	0.00	0.00	0.04	0.10	0.06
Exchangeable Mg	—	—	—	—	—	—	0.01	−0.08	0.65	0.91	0.85
Exchangeable K	—	—	—	—	—	—	—	0.00	0.00	0.01	0.01
Soluble P	—	—	—	—	—	—	—	—	0.36	0.03	0.32
pH	—	—	—	—	—	—	—	—	—	0.50	0.83
Total exchangeable bases	—	—	—	—	—	—	—	—	—	—	0.73

properties considered, the three which were most highly correlated with the GR_{50}(dsw) values were selected to be correlated in a multiple regression with the GR_{50} (dsw) values for cotton and Italian rye grass. The three factors having the highest correlations were organic matter, cation exchange capacity, and total exchangeable bases. For cotton, a multiple regression coefficient (R) of .968 was obtained and for Italian rye grass an R of .956 was obtained. These are very high correlations and should be of value for prediction purposes. The partial regression coefficients for the three factors used in the multiple regression, along with their standard errors and the prediction equations, are shown in Table 8.

Table 8. The multiple correlation of three soil factors with diuron GR_{50}(dsw) values for cotton and Italian rye grass.

Soil factor	Partial regression coefficient(b)[a]	Standard error of (b)	Mean value
I. Cotton (R = .968)			
A. Organic matter (X_1)	1.642**	0.345	2.68(%)
B. Cation exchange capacity (X_2)	0.248*	0.104	6.75(me.eq./100gm)
C. Total exchangeable bases (X_3)	−0.294*	0.098	4.27(me.eq./100gm)
D. Mean dry shoot yield cotton ($\bar{y}_1$)	——	——	3.72(g)
Prediction equation for cotton: $GR_{50}(dsw) = 1.642X_1 + 0.248X_2 - 0.294X_3 - 1.099$			
II. Italian rye grass (R = .956)			
A. Organic matter (X_1)	0.254*	0.092	—
B. Cation exchange capacity (X_2)	0.084*	0.028	—
C. Total exchangeable bases (X_3)	−0.062*	0.026	—
D. Mean dry shoot yield grass ($\bar{y}_2$)	——	——	0.553(g)
Prediction equation for grass: $GR_{50}(dsw) = 0.254X_1 + 0.084X_2 - 0.062X_3 - 0.430$			

[a] * and ** denote significance at the .05 and .01 levels of probability, respectively.

From a prediction standpoint, either organic matter or cation exchange capacity might serve as a practical indication of the level of toxicity which might be obtained from an application of diuron to a given soil. Just which of these factors would be best to use alone for prediction purposes is difficult to agree upon from theoretical considerations, since they are highly correlated one with the other ($r = .87$). However, from a practical standpoint organic matter would seem to be the better choice, since it has a slightly higher simple correlation with diuron toxicity than cation exchange capacity, and in addition, is easier to determine analytically.

At a glance one might assume that the interpretation of the results presented here would be greatly modified if the data were to be analyzed in terms of the amount of herbicide per unit volume of soil required to give a stated amount of growth reduction. Such is not the case. For example, by expressing the GR_{50}(dsw) values on a volume basis the correlation with organic matter was found to be 0.91 for both cotton and Italian rye grass. The values obtained expressing the GR_{50}(dsw) values on an oven-dry soil weight basis were 0.93 for cotton and 0.90 for Italian rye grass (Table 7). This comparison and others made but not presented here show that either of these two ways of expressing the data are valid.

Soil phosphorus, which has been reported elsewhere to influence diuron toxicity (1), was not observed to be related to toxicity in these studies. An examination of Table 2 indicates that the variation in types of colloids found in the soils investigated did not have a dominating influence on the toxicity of diuron.

Since the soils were taken from their natural states and used without addition of fertilizer, it is possible that some of the factors affecting diuron toxicity counteracted one another. For example, one would expect the toxicity of diuron to vary considerably from a sandy loam to a sandy clay loam to a clay loam of the same series. Yet, the results from the Cecil series presented in Table 6 did not reveal such a variation. It is possible that the phosphorus contents of the three soils (Table 1) prevented the expression of the anticipated relationship.

Frequently, in weed control practice the objective is to remove one plant species without causing injury to another. In this regard, it is of interest to determine whether or not the selectivity of herbicides is affected by soil-to-soil variation. Three carbamate herbicides were reported by Moore to be more selective on a loam soil than on a sand soil (8). Blouch and Fults found that trichloroacetic acid and isopropyl N–(3–chlorophenyl)carbamate are more selective on some soils than on others (2). The effect of soil factors on selectivity in the present studies is shown by the ratio GR_{20}(dsw) (cotton) ÷ GR_{80}(dsw) (grass). This ratio is presented for 12 soil types in Table 6. It is a selectivity index indicating how many times the rate required to give essential control of a grass (80 percent reduction) would be required to barely injure cotton (20 percent reduction). The selectivity of diuron varied little from soil to soil. The selectivity indices had a range of only 67 percent of the mean index as compared to ranges of 239 and 267 percent for the GR_{20}(dsw) (cotton) and GR_{80}(dsw) (grass) mean values respectively. In view of the possibility that the lowest and highest selectivity indices might be different, all soil properties in Tables 1, 2, and 3 for the soils having the extreme indices have been examined closely. No soil factor was found which would account for a difference in selectivity, if the extremes are indeed different.

Since the selectivity apparently does not vary, indications are that diuron might be used with equal success on all of the soils studied to remove a grass from a tolerant crop. This assumes that one knows the capability of a given soil for influencing the toxicity of diuron to plants. This point is obviously critical since the amount of diuron required to control grass on three soils was greater than that required to give injury to cotton on two other soils. From the correlations previously discussed, it appears that the level of organic matter in the soil might be used as a practical indication of the amount of diuron which would be required on a given soil to produce the highest degree of selective weed control. On a soil containing 0.8 percent organic matter, approximately 0.75 ppm of diuron was required to produce a GR_{50}(dsw) for cotton. For each 1 percent increase in organic matter, approximately 2.0 ppm additional diuron

was required to produce a GR_{50}(dsw) for cotton. Other workers also have found a high degree of correlation between the amount of soil organic matter and the activity of herbicides in soils (9, 10). Further research is needed to determine whether or not this relationship can be extended to pre-emergence type applications and to determine its utility under practical conditions.

The average selectivity index for these studies was 3.9 as calculated from Table 6. This is approximately the same degree of selectivity which has been observed for cotton in the Southeastern United States under field conditions using pre-emergence type applications of diuron. There is a theory which may be stated as follows: The difference in the depths from which small seeded grass and large seeded crop plants ordinarily become established causes the larger seeded plants to be more tolerant to pre-emergence applied heribicides than the smaller seeded plants (4). Since the diuron was mixed with the soil in these studies, depth of planting was not a factor and, according to the theory, the degree of selectivity should have been below that generally obtained with pre-emergence type applications. This apparent discrepancy warrants further study.

From Table 6, one observes that a GR_{50}(dsw) for cotton can be produced on some soils by adding as little as 0.78 ppm of diuron. Why is four to ten times as much required to give a GR_{50}(dsw) on other soils? Apparently a certain amount of diuron, dependent upon the particular soil involved, is bound to some soil fraction and thereby rendered nontoxic. Graphs of the data in Tables 4 and 5 show that for each soil there is a threshold value for diuron beyond which sharp reductions in plant growth are produced. However, even above this threshold value the particular soil involved influences the toxicity of additional diuron increments. The greater the threshold value, the greater the additional amount of herbicide required to bring about a given reduction (such as 50 or 80 percent) in plant growth.

SUMMARY

Cotton and Italian rye grass were grown on 12 soil types containing varying amounts of admixed diuron in an effort to demonstrate the effect of soil properties on the selectivity and phytotoxicity of herbicides. Dry shoot weights were recorded after 5 or 6 weeks growth under greenhouse conditions.

Approximately ten times as much herbicide was required to produce a 50 percent reduction in dry shoot weight on some soils as on other soils. For the experimental conditions employed, this variation was greater among the six marine soils used than among the six residual soils used. The degree of correlation between the amount of herbicide required to produce a 50 percent growth reduction and 11 soil properties was calculated. Organic matter content and cation exchange capacity were highly correlated with growth reduction. The types of colloids found in the soils were not observed to influence the phytotoxicity of diuron.

The selective herbicidal properties of diuron were not found to be influenced by soil properties. Apparently, equal success can be had

on many soils in removing a grass from a crop plant which is tolerant to diuron provided the amount of diuron required to give effective grass control is known. The use of soil organic matter level to predict this critical value for field conditions is suggested.

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The Role of Gibberellic Acid in Overcoming Bud Dormancy in Perennial Weeds. I. Leafy Spurge (*Euphorbia esula* L.) and Ironweed (*Vernonia Baldwini* Torr.)[1]

NEAL E. SHAFER and WARREN G. MONSON[2]

PERENNIAL weeds capable of vegetative reproduction comprise, as a group, some of our most serious weed problems. Eradication is difficult where new top growth can be produced repeatedly from underground buds. A time honored control method involves the cutting of all top growth with special tillage implements each time sufficient new growth has been produced. In this way food reserves in the root system of the weed are slowly depleted until all growth stops. Root systems of most creeping perennial weeds are supplied with numerous buds on either the crown, lateral roots or rhizomes. Removal of the top growth of such plants with either chemicals or tillage results in the activation of a small percentage of the available buds and new top growth is produced. The new growth thus produced tends to prevent further bud activation presumably through the maintenance of auxin levels unfavorable for growth of these buds. This phenomenon is often referred to as apical dominance. Food depletion of the root system would be faster if more buds could be stimulated to active growth prior to each cycle of top growth removal.

LITERATURE

Recently published results have brought renewed interest in a class of chemical compounds called gibberellins. The gibberellins are metabolites of *Gibberella fujikuroi* (Saw) Wr., a fungus organism causing the "crazy seedling" disease of rice which is characterized by pronounced stem elongation. Japanese scientists were the first to report the existence of these gibberellin compounds. Yabuta, Sumiki, Hayasi and others (2, 5, 6) have numerous publications on the isolation and action of gibberellins. They found that the gibberellins stimulated germination of barley, wheat and rice. There was an increase in the amount of amylase present in the seeds treated with gibberellins. Japanese, English and American workers have isolated and identified three chemically different forms. These have been referred to as gibberellin A_1 or A, gibberellin A_2, and gibberellin A_3 also referred to as gibberellic acid (GA). The latter has been most widely investigated although all three types appear to give similar results.

Plants which have shown marked increases in growth rates following treatment include such ornamentals as geranium, poinsettia,

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snapdragon and rose. Crop plants which have shown increased growth are snapbean, soybean, peanut, pepper, sugar cane, tobacco and tomatoes (3). British workers (1) report stimulation of growth following treatment of wheat, oats, several grasses, clover, cucumbers, tomatoes and peas. Potato tubers sprouted without a normal dormant or resting period and apical dominance was apparently reduced because branched sprouts occurred in almost all eyes. California workers (4) have shown that dormant potato tubers dipped in gibberellic acid resulted in 90% of the tubers sprouting in one month where only 11% sprouted without the chemical treatment. The reported possible role of gibberellic acid in overcoming apical dominance and dormancy in potatoes has led to the present investigation on the response of dormant buds of leafy spurge and ironweed to various types of treatments with this new growth substance.

METHODS AND MATERIALS

A preliminary experiment was designed to compare lanolin paste and water spray as methods of applying gibberellic acid to the plants and to determine the effects on dormant buds. Twelve leafy spurge plants were selected which had been growing in 6-inch clay pots in the greenhouse for approximately 3 months. Each of the test plants had 8 to 12 inches of topgrowth and most had two shoots. Three ironweed plants, each with one shoot about 0.5 cm in length were also treated.

The leafy spurge plants were divided into 4 groups of three plants each, and each group was handled differently prior to treatment with gibberellic acid. Group A plants were left intact and lanolin paste or a water spray was applied to the exposed crown buds. Group B plants had the topgrowth removed at the soil line and the paste or spray treatment was made on the exposed crown buds. The nature of a directed spray application resulted in some of the treatment being intercepted on arrested shoots and the bases of stems. Group C plants were left intact and treatment was made on the foliage. Here the lanolin paste was applied only on the shoot apex. The water spray was applied to the point of runoff as an overall treatment. Group D plants had approximately one inch of the apical portion of all stems removed prior to treatment of the cut tips with GA. The three ironweed plants comprised a fifth group and treatments were applied to intact topgrowth.

One plant was left as a check in each group. Of the two remaining plants, one was given a spray treatment with a 0.1% aqueous solution of Tween 20 containing 100 ppm of gibberellic acid and the other was treated with a lanolin paste mixture containing 1% (w/w) gibberellic acid. Bud numbers and measurements of visible dormant buds were recorded at the beginning of the experimental period. Counts on new shoots and lengths of these shoots were taken twice during the first week after treatment, then at weekly intervals for the next 3 weeks.

In the second experiment all treatments were applied as foliage sprays. Leafy spurge plants were selected for uniformity in age and

development and were similar in growth history to those used in the first test. Five treatments were employed on these plants: 0, 25, 50, 100, and 500 ppm gibberellic acid in 0.1% Tween 20 aqueous solution. The same GA treatments were used on ironweed plants, less the 25 ppm rate. Three plants were used per treatment in this experiment. Two additional treatments were applied to ironweed roots which had produced no top growth. These were solutions containing 100 and 500 ppm of gibberellic acid applied as a soil treatment at the rate of 5 cc per pot. Data were collected twice weekly on the number of newly activated shoots, length of new growth, and number of newly emerged buds. Observations were also made on general appearance of new growth and effects of the chemical on flowering.

RESULTS AND DISCUSSION

The new growth per plant for the first experiment is presented in Figure 1. From these data it would appear that the lanolin paste treatment was more effective when applied to the buds. This was evident from the growth obtained in the first two groups of plants

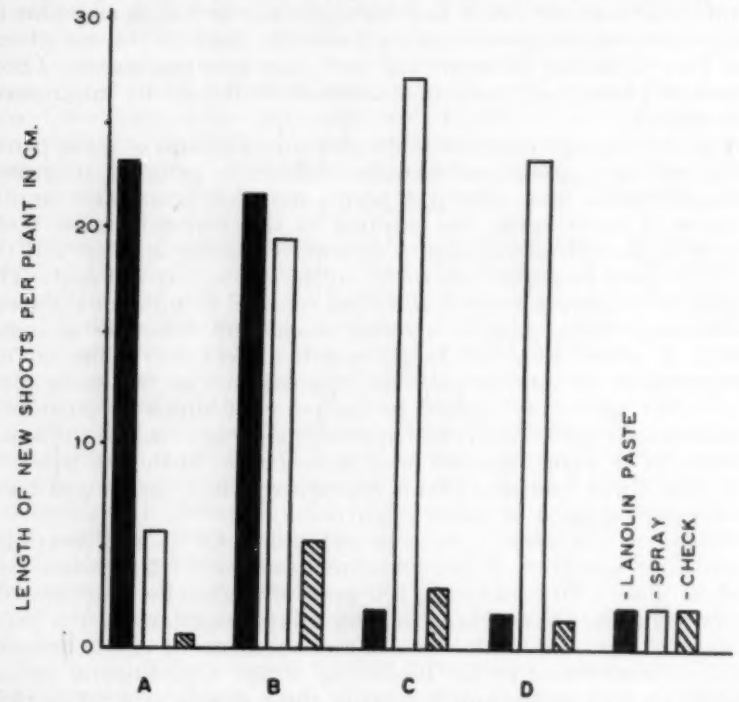

Figure 1. New growth produced or induced on leafy spurge plants 4 weeks after treatment with gibberellic acid. Group A—topgrowth left intact, treatments applied to buds. Group B—topgrowth removed, treatments applied to buds. Group C—topgrowth left intact, foliage treated. Group D—shoots decapitated, cut tips treated.

when compared to the second two groups. The lanolin paste treatment was superior to the spray treatment on the group A plants where the plant was left intact and the exposed buds were treated. There was not much difference between treatments on group B plants where the topgrowth was removed and the exposed buds were treated. The ironweed plants showed very little response to the treatments with gibberellic acid and no perceptible difference between treatments.

By the end of the first week after treatment there was evidence of new shoot development on all treated plants in group A, B, C, and D. There was also some new growth produced from dormant buds on the check plant from which the topgrowth had been removed. It was noted that the removal of topgrowth from a plant did not induce as much new growth as was induced following treatment with GA.

From the data it appears that the most important information evolving from the first test may be the fact that spraying the solution of GA on the intact plant induced more growth than the lanolin paste treatments. This would appear to be fortunate if these findings should result in practical applications for controlling perennial weeds.

In the second experiment using various concentrations of GA on leafy spurge, some indications of new shoot development were evident 3 days after treatment and definite growth responses were shown at the end of 1 week. This was evidenced both by new growth on old shoots and in the production of new shoots. Table 1 shows

Table 1. Effects of several concentrations of gibberellic acid on the development of leafy spurge plants in the greenhouse. Final counts were taken 3 weeks after treatment.

Observation	Gibberellic acid—ppm				
	0	25	50	100	500
No. of buds at treatment	7	20	3	11	19
No. new shoots	0	9	5	9	15
No. new buds emerged	0	0	4	3	9
Total effect (New shoots plus new buds)	0	9	9	12	24

the numbers of new shoots per treatment and number of buds which emerged during the 3 weeks in which counts were made. From these data it is apparent that more new shoots are activated at the 500 ppm treatment than at any of the other treatments. Also, in the 50 ppm treatment, there were more new shoots activated than there were visible buds at treatment date. This would indicate that buds other than those which are visible above the soil may be activated by such treatment. There was no measurable growth on any of the check plants during the course of the experiment. Figure 2 shows the number of new shoots and their growth 3 weeks after treatment. It should be noted that this picture does not include new growth which was induced on the old shoots present at treatment date, since these shoots were removed from the plants.

Figure 2. New shoot growth on leafy spurge 3 weeks after treatment with gibberellic acid. Old treated shoots have been removed. Treatments left to right: 0, 25, 100, and 500 ppm gibberellic acid applied as foliage sprays in 0.1% Tween 20 water solution.

Figure 3 shows graphically the average new growth per plant which occurred during the 3 weeks following treatment. That there is a difference in growth rate between treatments is quite evident. There was very little difference in the growth rate or in the new growth produced between the 25 and 50 ppm treatments. There was a considerable increase in the growth rate and in the total new growth produced as the treatment concentrations were increased to 100 and 500 ppm of GA. The growth rate of the plants receiving 100 and 500 ppm treatments had not diminished appreciably even at the end of 3 weeks. This appears to indicate a continued response to the GA treatment at the higher concentrations.

Growth induced by GA was distinguishable by its lighter green color and in most cases by more attenuate shoots. In several cases treated plants branched profusely, often producing 5 or 6 branches as much as 25 cm long. This appears to be further evidence that GA may have an effect in overcoming apical dominance. Some treated plants developed greatly elongated umbel branches. Considered overall, the effect on flowering appeared to be variable; in some cases new growth produced flowers and in others it did not. Flowers on some treated plants later produced vegetative growth from the tip

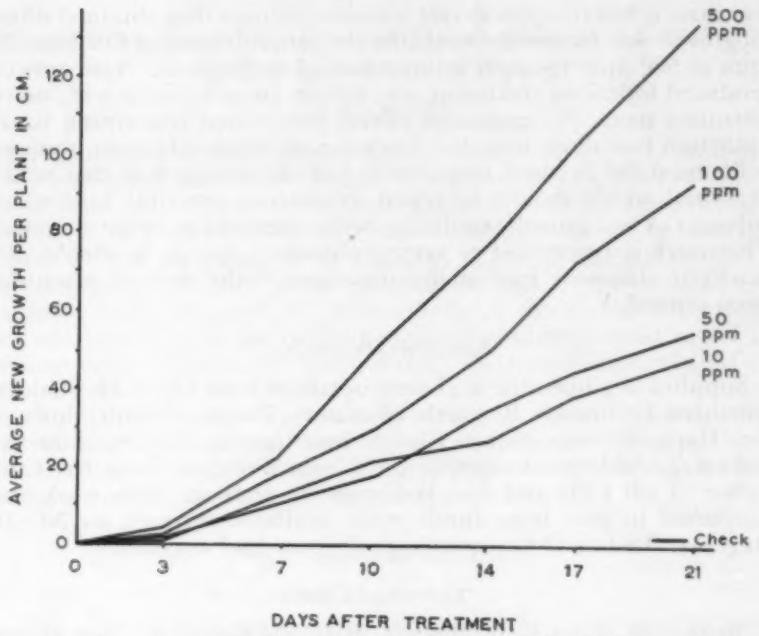

Figure 3. The new growth on leafy spurge plants following treatment with four concentrations of gibberellic acid. Values are averages of three plants per treatment. All treatments were foliage sprays applied in 0.1% Tween 20 water solution.

of the umbel branches. It may be that flower production following treatment with GA, or the lack of flower production, is a function of the specific stage of development of the plant at the time of treatment, or as Figure 2 suggests, the amount of GA used may be a factor in flower production.

SUMMARY

Gibberellic acid was used both as a foliage spray and in lanolin paste on leafy spurge and ironweed in an attempt to activate dormant buds. Ironweed did not respond to either method of treatment nor did it respond to soil applications. Where applications were made directly on dormant buds of leafy spurge, treatment with lanolin paste was superior to a water spray. When topgrowth was removed prior to treating the exposed dormant buds, the spray treatment was as effective as the lanolin paste treatment. Spraying the intact foliage of leafy spurge with GA resulted in the most new shoot growth when compared to the other methods of treatment tested.

With leafy spurge, GA stimulated growth on emerged dormant buds, caused branching and new shoot development on old shoots, and stimulated the emergence of new buds. The effects of the GA stimulant were similar to those associated with the removal of apical

dominance, but the growth rate was several times that obtained when topgrowth was removed. Increasing the concentration of GA from 25 ppm to 500 ppm resulted in increased plant response. New growth produced following treatment was lighter green in color with more attenuate stems. No consistent effects were noted concerning floral induction but those that did develop were distinctly more ramose.

Plants differ in their response to GA. It is suggested that other perennial weeds should be tested. Numerous practical aspects involving GA and growth regulating herbicides need to be investigated. This work is recognized as very preliminary, but it is offered primarily to stimulate further investigations in the field of perennial weed control.

ACKNOWLEDGEMENT

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Absorption, Translocation and Metabolism of 2,4–D–1–C^{14} in Pea and Tomato Plants[1]

S. C. Fang[2]

The absorption and translocation of radioactive 2,4–D in bean plants has been studied by many workers (2, 4, 5, 7). The translocation of radioactive carbon from applied 2,4–D has been demonstrated to be more rapid in susceptible bean plants than in resistant plants such as corn and wheat seedlings (2, 3, 4). The difference in reaction of 2,4–D with plant constituents was further established between these two types of plants (3, 6). A compound designated as "unknown 1" was the major metabolic product formed in 2,4–D treated bean plants while "unknown 3" was found mainly in 2,4–D treated corn and wheat seedlings.

This article presents the results of some experiments to determine (1) the rate of absorption and translocation of 2,4–D in pea and tomato plants and (2) whether or not unknown 1 will always be the major metabolic product in the susceptible plants.

Materials and Methods

Absorption and Translocation.

The method used for the combustion of the plant samples and the measurement of radioactivity have been described elsewhere (1). A sample of 2,4–D–1–C^{14}, with a specific activity 1.47×10^6 counts per minute per mg, was used in these experiments.

The pea plants (*Pisum sativum* var. Alaska) and tomato plants (*Lycopersicum esculentum* var. Bonney Best) used in these experiments were grown individually in 4 inch pots containing fertile soil under greenhouse conditions. Twenty-four uniform plants each of pea and tomato seedlings were selected. Fourteen days after emergence, the pea plants, at 3 to 4 leaf stage, were treated with 10 μg of 2,4–D–1–C^{14} on the lowermost leaf of each plant. A 95% ethanol solution containing 0.1% radioactive 2,4–D and 0.2% Tween–20 (w/v) was used for treatment. Each group of eight plants was harvested after 1, 3 and 7 days of treatment. Six plants were sectioned into different parts according to the diagram in Figure 1. The surfaces of treated leaves were washed with 50% ethanol to remove the unabsorbed 2,4–D. The sections were pooled and dried in a vacuum oven at 60° C for 24 hours. An aliquot of each ground sample was analyzed for C^{14} by the usual microcombustion procedure (1). The carbon dioxide trapped in NaOH solution was precipitated with barium chloride. The activity of $BaCO_3$ was counted with a thin mica window G-M counter (1.8 mg/cm^2) and corrected to zero thick-

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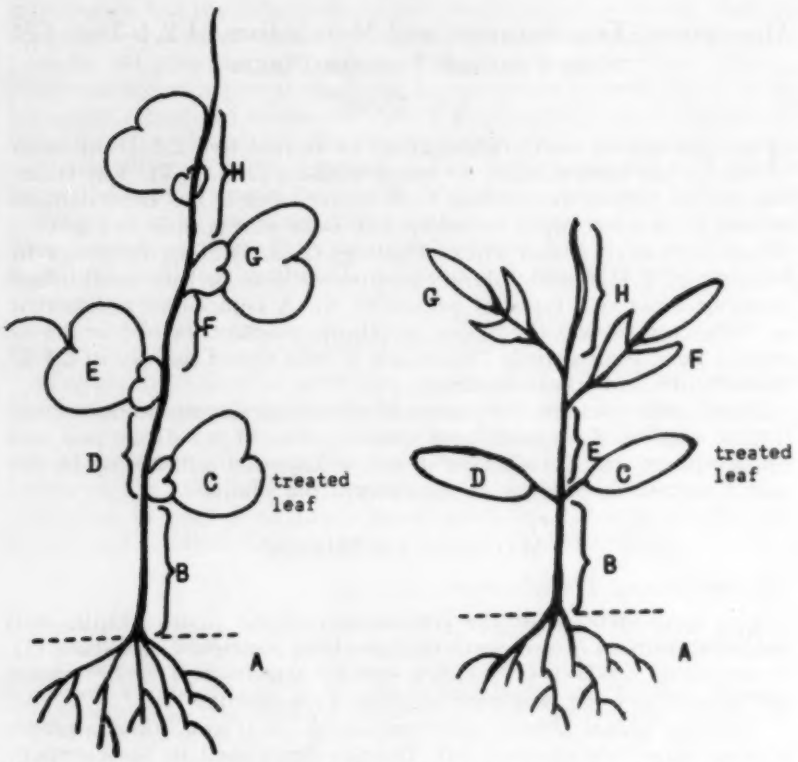

Figure 1. Diagram showing parts into which plants were sectioned for radioassay. Left, pea; right tomato.

ness. Two other plants from each group were dried between sheets of blotting paper and were then used for the preparation of radioautographs.

Approximately 3 to 4 weeks after planting, the tomato plants, at the second true leaf stage, were treated in the same manner with 20 μg of radioactive 2,4–D per plant. The treatment was made on the midrib of one primary leaf. Six plants were harvested at 1, 3 and 7 days after treatment. One plant from each group was used for making a radioautograph and the other five plants were sectioned into plant parts. After drying the radioactivities of each sample and of the alcohol washings of treated leaves were determined.

Metabolism of 2,4–D–1–C^{14}.

In the study of 2,4–D metabolism the pea and tomato plants were treated in similar fashion. Twenty μg of radioactive 2,4–D was used in the treatment for each plant. After harvesting and washing the unabsorbed 2,4–D from the treated leaves, the plant parts were homogenized individually in a Waring blendor with 80% ethanol.

The amounts of 2,4–D and other radioactive metabolic products in each ethanol extract were estimated by the technique of one dimensional paper partition chromatography. The chromatograms were developed descendingly either with aqueous phenol or ammonium hydroxide–n–butanol (1:4 v/v) systems. The relative radioactivity of compounds containing C^{14} in alcohol extract was estimated according to the method described previously (3).

RESULTS AND DISCUSSION

Table 1 summarizes the results of radioactive carbon distribution in pea plants after receiving 2,4–D–1–C^{14} treatment. Approximately one half or more of the applied 2,4–D was found to be unabsorbed

Table 1. Absorption and translocation of C^{14} activity in pea plants which received 10 μg carboxyl-C^{14}-labeled 2,4-D treatment per plant.

Plant section[a]	1 day			3 days			7 days		
	Dry weight —mg	Total activity —cpm	Translocation and accumulation— %	Dry weight —mg	Total activity —cpm	Translocation and accumulation— %	Dry weight —mg	Total activity —cpm	Translocation and accumulation— %
A	296.1	2480	2.81	386.6	3940	4.46	292.6	1010	1.15
B	50.6	2720	3.08	51.7	1950	2.21	49.2	270	0.31
C	60.1	9860	11.18	51.3	3700	4.19	15.4	1930	2.19
D	14.0	365	0.41	15.1	320	0.36	15.9	70	0.08
E	152.0	630	0.71	136.1	450	0.51	72.8	0	0.00
F	8.5	160	0.18	14.2	240	0.27	18.2	100	0.11
G	146.7	510	0.58	158.3	750	0.85	58.4	350	0.40
H	127.4	630	0.71	132.7	980	1.11	111.4	370	0.42
Washing	——	42500	48.18	——	62500	70.86	——	45400	51.47
Total C^{14} activity recovered	——	59855	67.84	——	74830	84.82	——	49500	56.13

[a]See Figure 1 for plant section.

in all three samples. The per cent of C^{14} activity accumulated in all plant parts was 19.7%, 14.0% and 4.7% for 1, 3 and 7 day samples respectively. The results suggest that pea plants do not further absorb the applied 2,4–D from the leaves after one day, as no great difference was observed in the recovery of 2,4–D by washing the surface of the three treated leaf samples. Because the amount of C^{14} recovery from pea plant tissues decreased when the time before harvest was increased, it is presumed that the loss of activity was due to decarboxylation of 2,4–D in the plant with subsequent release as CO_2. The rate of breakdown of 2,4–D in pea plants, as indicated in this experiment, was far more rapid than in bean plants (2). This evidence fits in with the general observation from field trials that pea plants always recover sooner than bean plants from 2,4–D treatment.

The distribution pattern of C^{14} in pea plants as shown in Figure 2 was different than that found in bean plants. Except for that in the treated leaf, most of the radioactivity moved downwards and accu-

Figure 2. Radioautogram of pea plant harvested 3 days after receiving 10 μg of 2,4–D–1–C^{14}; 2,4–D was applied on the lowermost leaf.

mulated in the lower part of the stem and the roots. As time progressed to the third day, more radioactivity was found moving out of the treated leaf and accumulating slightly more at both the top portions and the roots. Results of the 7-day pea plants indicated that the radioactivity in all plant tissues was radically decreased.

The results on the absorption of 2,4–D–1–C^{14} and subsequent translocation of C^{14} in the tomato plant are shown in Table 2. The amount of 2,4–D in the washings was decreased from 60.7% in the 1 day sample to only 7.5% in the 7 day one. Also, the activity in the treated leaves increased from 17.2% of the amount applied in the 1 day sample to 48.3% in the 7 day sample. These data suggest that the applied 2,4–D was continuously absorbed by the tomato leaves.

Table 2. Absorption and translocation of C^{14} activity in tomato plants which received 20 μg carboxyl-C^{14}-labeled 2,4-D treatment.

Plant section[a]	1 day			3 days			7 days		
	Dry weight —mg	Total activity —cpm	Translocation and accumulation— %	Dry weight —mg	Total activity —cpm	Translocation and accumulation— %	Dry weight —mg	Total activity —cpm	Translocation and accumulation— %
A	80.4	940	0.64	161.5	2290	1.55	223.0	2200	1.49
B	36.8	310	0.21	70.1	1130	0.77	118.3	6000	4.06
C	31.2	25320	17.15	38.3	41100	27.86	40.3	71300	48.34
D	18.4	45	0.03	29.4	50	0.03	26.1	120	0.08
E	14.1	285	0.19	40.9	390	0.26	70.4	810	0.55
F	90.1	540	0.37	132.6	240	0.16	128.8	190	0.13
G	75.0	230	0.16	129.0	240	0.16	176.2	320	0.22
H	32.7	195	0.13	104.5	220	0.15	176.4	90	0.06
Washing	—	89500	60.68	—	82400	55.86	—	11100	7.51
Total C^{14} activity recovered	—	117365	79.56	—	127670	86.80	—	92130	62.44

[a]See Figure 1 for plant section.

This observation differed completely from the experiment with pea plants. Approximately 85 to 90% of the activity absorbed remained in the treated leaves. Again, the radioactive carbon accumulated more in the lower part of the stem and the roots than in the upper stem and leaves. The C^{14} accumulation pattern of tomato plants as shown in Figure 3 also differs from what had been found in the bean plants (2).

Table 3 shows the major radioactive compounds present in the alcoholic extracts of pea and tomato tissues. In the case of pea plants,

Table 3. Percentage of total radioactivity represented by major compounds found in the 80% alcohol extract of leaves, stems and roots in pea and tomato plants treated with 2,4-D-1-C^{14}.

Plant sections	Time of treatment— days	Major radioactive compounds—pct.					
		2,4-D		Unknown 1		Unknown 3	
		Pea	Tomato	Pea	Tomato	Pea	Tomato
Leaf	1	91	48	6	3	2	32
	3	62	46	12	6	10	32
	7	59	41	1	18	11	20
Stem	1	90	57	7	2	2	25
	3	48	82	40	3	2	8
	7	28	73	3	7	16	12
Root	1	87	78	7	1	1	11
	3	54	81	41	3	2	12
	7	23	65	6	8	8	5

both 2,4–D–protein–complexes, which were designated as unknown 1 and unknown 3 in previous papers (3, 6), were found in all alcoholic extracts. Maximum concentration of unknown 1 was found in all parts of 3-day pea samples while the amount of unknown 3 was small. However, unknown 1 disappeared almost completely in all parts of the 7-day samples while the amount of unknown 3 increased

Figure 3. Radioautogram of tomato plant harvested 3 days after receiving 20 μg of 2,4–D–1–C^{14} treatment; 2,4–D was applied on the right primary leaf.

slightly. Coincidentally, all pea plants appeared to recover completely from the 2,4–D treatment. The isolation of a workable amount of pure unknown 1 has been tried in this laboratory but the work was found to be rather tedious, therefore, it has not yet been proven whether or not unknown 1 is the physiologically active compound. However, it is quite logical to assume that unknown 1 may directly

play a part as an antimetabolite disturbing the normal metabolic process, or that the 2,4–D molecule might react with some vital constituents such as vitamins and coenzymes, during the formation of unknown 1, and cause a disturbance in metabolic systems. The appearance of many radioactive spots on the paper chromatogram prepared from all 7-day samples indicated the incorporation of C^{14} from radioactive 2,4–D into other plant constituents.

In the case of tomato plants, even at different stages of growth, unknown 3 was always found to be the major metabolic product. Maximum concentration of unknown 3 in this case was reached in 1-day samples. Results from 1, 3, and 7-day samples show that the concentrations of unknown 3 were highest in the leaf, next highest in the stem and least in the root. No experiment has been conducted to determine specifically the site of unknown 3 formation. If the rates of movement of 2,4–D and unknown 3 from the leaf to the other plant parts are equal and unknown 3 is also formed in the stem and root tissues, then the concentration of unknown 3 in these tissues would be expected to be higher. However, the results indicate that the concentration of unknown 3 is smaller in the stem and root than in the leaf, therefore, it is likely that the movement of unknown 3 is slower than the movement of 2,4–D or does not move at all in the tomato plant. This experiment also reveals that unknown 1 is not always the major radioactive product from susceptible plants after receiving 2,4–D treatment. Therefore, the growth-inhibiting effect of 2,4–D in the bean, pea and tomato plants and its failure to produce significant inhibition in corn and wheat plants is not due to the differences in the manner in which 2,4–D reacts with the plant constituents in each case.

SUMMARY

A study has been made of the absorption, translocation and the fate of 2,4–D–1–C^{14} in the pea and tomato plants. It was found that the pea plants do not further absorb the applied 2,4–D from the leaves after the first day while the tomato plants continuously absorb the applied 2,4–D during the 7 days presentation period. The translocation of C^{14} to the apical portion of the pea and the tomato plants seems to be slower than with bean plants. In contrast to the 2,4–D accumulation pattern in bean plants (2) most of the activity moves downward and accumulates in the lower part of the stem and the roots of the pea and tomato plants.

A part of the applied 2,4–D is incorporated in a few days into other compounds. Two major compounds designated as unknown 1 and unknown 3 were found in the 80% ethanol extracts of plant tissues from both 2,4–D treated pea and tomato plants. The unknown 1 is found in a greater concentration in pea plants while the unknown 3 is the major radioactive metabolite in tomato plants. Therefore, it suggests that the growth-inhibiting effect of 2,4–D in the susceptible plants and its failure to produce significant inhibition in resistant plants is not due to the differences in the manner in which 2,4–D reacts with the plant constituents.

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The Response of Certain Crops to 2,4–Dichlorophenoxyacetic Acid in Irrigation Water. Part III. Concord Grapes[1]

V. F. Bruns and W. J. Clore[2]

Field studies have been conducted at the Irrigation Experiment Station, Prosser, Washington, to determine the effects of 2,4–dichlorophenoxyacetic acid (2,4–D) in irrigation water on certain crop plants. The possibilities of contaminating irrigation water through the use of 2,4–D for weed control, particularly on ditchbanks, prompted these investigations. The response of Red Mexican beans and sugar beets to 2,4–D in irrgation water has been reported (1, 2). This publication deals with Concord grapes, a woody-type of crop plant.

In earlier studies, Clore and Bruns (3) found that Concord grapes were extremely sensitive to foliar applications of 2,4–D. Grape leaves in those studies were malformed even by the smallest dosage applied—0.0001 microgram. Lack of information on the sensitivity and response of Concord grapes to soil applications of 2,4–D, especially when applied in irrigation water, instigated the study reported herein.

Materials and Methods

The materials and methods used in this experiment were similar to those previously described (1, 2). The experiment was conducted on Sagemoor very fine sandy loam soil with a depth of 60 inches to bedrock.

After proper fertilization and tillage of the soil, 30 plots, each 10 x 20 feet, were laid out in 3 blocks on contour with a zero grade. The distance between plots was at least 48 inches and the alleyways between blocks were 10 feet wide.

Early in April, 1953, eight 2-year-old Concord grapes were planted in each plot. Four rows of 2 plants each in a staggered arrangement provided adequate growing space and permitted ditching for irrigation.

Six 600-gallon metal tanks, mounted on sleds and equipped with valve, hose, and boom attachments, were used throughout the experiment for applying the irrigation water and the 2,4–D in accurately measured quantities. The problem of measuring and discarding the effluent was eliminated by damming the irrigation furrows at each end of the plots and by regulating the flow from the tanks (Figure 1).

[1]Contribution of the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Washington Agricultural Experiment Stations, cooperating. Scientific Paper No. 1633. Washington Agri. Exp. Stations.

[2]Agronomist, Crops Research Division, ARS, USDA, and Horticulturist, Washington Agricultural Experiment Stations, respectively, Irrigation Experiment Station, Prosser, Washington. The assistance of C. J. Cox and Alf Hammer in conducting the field work is acknowledged. H. W. Potter helped prepare the photographs.

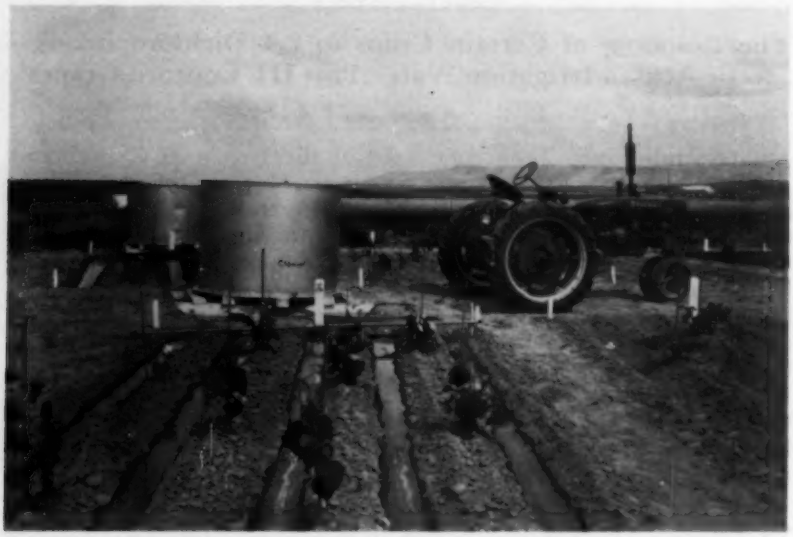

Figure 1. Plot and grape plant arrangement, equipment, and method used in applying the irrigation water.

From June 29 to July 2, 1953, 2,4–D acid dissolved with triethanolamine was applied at rates of 0, $^1/_{16}$, $^1/_8$, $^1/_4$, $^1/_2$, 1, 2, 4, 8, and 16 lb/A in 3 acre-inches of irrigation water. At this time, the grapes were growing vigorously and averaged 3 shoots per plant. The shoots averaged 15 inches in length and 10 leaves per shoot.

The response of the foliage and roots of the grape plants to the 2,4–D treatments was observed and recorded during the 1953 season. The plots were maintained during 1954 in order to observe and measure the possible carry-over effects of the previous year's treatments.

RESULTS AND DISCUSSION

1953.

Early symptoms of injury to the foliage were noted within 1 week after the 2,4–D treatments. Leaves of affected vines tended to droop and wilt. Moreover, both the upper and lower surfaces of these leaves appeared to turn dark and to lose their natural luster.

Within 2 weeks, the effects of the 2,4–D treatments were more pronounced. As recorded in Table 1, rates of one-half pound or less per acre caused no detectable symptoms of damage. The foliage of a number of plants on plots receiving rates of 1 pound or more per acre was severely damaged or killed, whereas other plants on the same plots appeared normal (Figure 2). Leaves of plants severely injured were wilted and burned. Some leaves turned black. With few exceptions, severely damaged plants died within 2 or 3 weeks,

Table 1. The effects of 2,4-D in irrigation water on the leaves of Concord grapes, 1953.

2,4-D appl. lb/A (6/29–7/2/53)	Number of plants with leaves											
	Normal			Wilted			Severely injured			Killed		
	7/15	7/28	9/30	7/15	7/28	9/30	7/15	7/28	9/30	7/15	7/28	9/30
0	24	24	24	0	0	0	0	0	0	0	0	0
1/16	24	24	24	0	0	0	0	0	0	0	0	0
1/8	24	24	24	0	0	0	0	0	0	0	0	0
1/4	24	24	24	0	0	0	0	0	0	0	0	0
1/2	24	24	24	0	0	0	0	0	0	0	0	0
1	22	22	22	0	0	0	2	1	2	0	1	0
2	20	20	21	1	1	0	2	0	0	1	3	3
4	16	15	14	1	0	0	0	1	2	7	8	8
8	8	9	7	6	0	0	2	2	4	8	13	13
16	10	11	0	4	1	0	3	1	12	7	11	12

Figure 2. Top: Untreated check. Bottom: Varying degrees and types of injury to grape foliage caused by the heavier rates of 2,4–D in irrigation water.

whereas a number of those apparently uninjured during the initial stages continued to grow, even on plots receiving 8 pounds of 2,4–D per acre. The heavier rates, especially 8 and 16 lb/A, caused some additional damage and death of plants as the season advanced.

No malformation of leaf growth as produced by foliar applications of 2,4–D (3) was found. Injury symptoms were like those which might

be expected to result from severing a part or all of the root system from the plant. Several plants were excavated and the roots were examined. The roots of plants whose foliage appeared lethally affected by the treatments were damaged extensively (Figure 3).

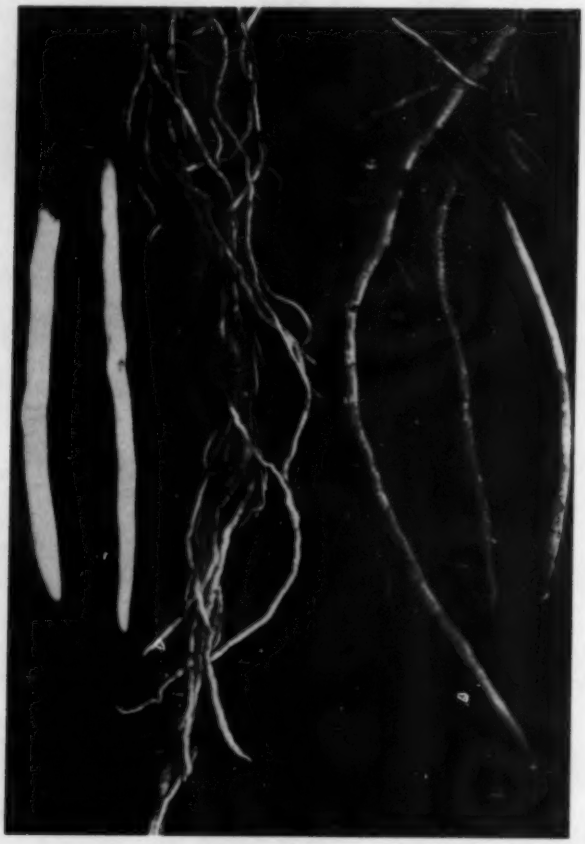

Figure 3. Root systems and end sections of fibrous roots of Concord grape plants. Left: Untreated check. Right: Severely damaged by 2,4–D in the irrigation water. Note discoloration and swollen tips of remaining fragments.

Fibrous roots for the most part were destroyed. Remaining fragments of the root systems appeared discolored and somewhat enlarged at the tips. Other plants with or without apparent foliage injury, especially on plots receiving the heavier rates of 2,4–D, showed varying degrees of such root damage. Translocation of appreciable quantities of 2,4–D from the roots to the foliage was not indicated by these observations. Differences in depth, distribution, and development of the root systems of the new plantings undoubtedly existed at the time of treatment. With more soil to intercept and adsorb the 2,4–D, a deeper, less fibrous system would be less subject

to damage than a shallower, spreading system. This may explain why some plants were injured or killed whereas others on the same plots were not lethally or visibly damaged.

The growth of a number of surviving plants was retarded, although symptoms of actual 2,4–D injury were not apparent in the foliage. Shoot development during the season was considered a fairly reliable criterion of the comparative amount of injury, especially root damage, caused by the 2,4–D treatments. Measurements of shoot elongation (weighted means) for seven different dates during the growing season are presented in Table 2. Duncan's (4) method of comparison of the treatment means (5 percent level of probability) was used in the analyses of the data.

Table 2. Average shoot elongation (inches) of Concord grapes for seven different intervals in 1953 after applications of 2,4-D in irrigation water.

2,4-D appl. lb/A 6/29–7/2/53)	Date of shoot measurement[a]						
	7/15/53 (13 days)	7/20/53 (18 days)	7/27/53 (25 days)	8/6/53 (35 days)	8/21/53 (50 days)	8/31/53 (60 days)	9/30/53 (90 days)
0	7.3 a	10.0 a	13.4 a	21.0 a	31.1 a	35.3 a	38.1 a
1/16	6.8 a	9.6 a	13.3 a	20.2 a	31.8 a	35.3 a	38.6 a
1/8	6.0 ab	8.3 ab	12.5 a	21.3 a	32.2 a	36.0 a	40.6 a
1/4	5.8 ab	8.6 ab	12.4 a	20.3 a	31.5 a	35.7 a	38.8 a
1/2	5.3 ab	7.4 abc	10.6 ab	17.9 a	28.6 ab	31.8 ab	33.9 ab
1	4.3 bcd	5.8 cd	8.0 b	13.3 b	22.7 b	25.4 bc	27.0 bc
2	4.8 c	6.5 bc	8.4 b	13.0 b	21.2 b	23.1 c	25.5 c
4	3.1 cd	3.5 de	4.3 c	6.4 c	8.8 c	9.8 d	11.3 d
8	2.1 d	2.5 e	3.0 c	3.9 c	4.6 c	5.1 d	5.2 d
16	2.2 d	2.6 e	2.9 c	3.3 c	3.5 c	3.5 d	3.7 d

[a]Means with the same letters do not differ significantly at the 5% level of probability.

Shoot elongation was not inhibited during 1953 by the treatments of ¼ pound or less of 2,4–D per acre. The rates from 1 to 16 lb/A retarded shoot growth, with the 4, 8, and 16 pounds causing greater inhibition than the 1 and 2 pounds. The rate of ½ lb/A apparently was the borderline dosage. The measurement means of this rate are in the group which is significantly less than the check and also in the group with the check. However, the means of the ½-pound rate always fall in the former group (except for the 35-day period). Also, the means of this rate are consistently less than those of the check. Thus, it seems reasonable to assume that the ½-pound rate caused measurable damage up to and including the 90-day period.

1954.

The percentages of plants killed by treatments the previous year were determined conclusively early in 1954. No plants were killed by the applications of 1 pound or less of 2,4–D per acre in irrigation water. However, the rates of 2, 4, 8, and 16 pounds were lethal to 13, 33, 65, and 54 percent of the plants, respectively.

Observations and measurements of shoot growth of surviving plants were continued during 1954. The measurements are recorded in Table 3. Early growth on May 18 showed no significant differences in shoot elongation between treatments. However, by June 17, significant retardation of shoot growth had occurred on plots treated

Table 3. Average shoot elongation (inches) of Concord grapes for three different intervals in 1954 after application of 2,4-D in irrigation water.

2,4-D appl.—lb/A (6/29–7/2/53)	Date of shoot measurement[a]		
	5/18/54	6/17/54	9/7/54
0	10.7 a	27.2 ab	108.7 ab
1/16	7.6 a	25.6 ab	107.6 ab
1/8	6.6 a	20.9 bc	103.6 abc
1/4	8.4 a	30.9 a	115.4 a
1/2	8.9 a	26.7 ab	110.9 ab
1	9.3 a	25.2 ab	89.3 c
2	5.4 a	22.9 ab	106.4 abc
4	7.1 a	24.4 ab	93.1 bc
8	9.8 a	26.4 ab	97.8 abc
16	3.9 a	13.2 c	68.9 d

[a]Means with the same letters do not differ significantly at the 5% level of probability.

in 1953 at the rate of 16 lb/A. No symptoms of damage other than restricted shoot elongation were noted. All other treatment means fell within groups containing that of the untreated check.

As measured on September 7, 1954, shoot development was still significantly less on plots treated at the 16-pound rate in 1953. Except for the 1-pound rate, all other treatment means were within groups which included the check means. The means of the 4- and 8-pound treatments tended to lose rank as the season advanced, but the differences between these and the check mean merely approached significance at the end of the season. The variable correlation between these treatment means and treatment rates would tend to corroborate an earlier deduction that the depth and distribution of the root systems at the time of treatment were contributing factors in the experiment. Carry-over effects of the 2,4–D treatments apparently were indirect in nature. Restricted shoot growth during the second season appeared to be correlated with the extent of the initial root damage, the time required to recover from such damage, and the ability of the plants to develop new root systems to support normal growth.

SUMMARY

1. Two-year-old Concord grapes were planted and treated with 2,4–D at rates of 0, $^1/_{16}$, $1/8$, $1/4$, $1/2$, 1, 2, 4, 8, and 16 lb/A in 3 acre-inches of irrigation water on June 29 to July 2, 1953.

2. The rates of 2, 4, 8, and 16 pounds per acre were lethal to 13, 33, 65, and 54 percent of the plants, respectively, whereas lesser rates caused no death of plants.

3. Root systems of injured plants were partially or completely destroyed. Remaining portions or fragments showed varying degrees of discoloration and of tip enlargement. Depth, distribution, and development of the root systems at time of treatment apparently was an important factor in the experiment.

4. Rates from $1/2$ to 16 lb/A inhibited shoot growth during 1953. Indirect carry-over effects restricted growth in 1954 also on the 1- and 16-pound plots.

5. Foliage symptoms of injury included wilting, chlorosis, and/or desiccation. No malformation of leaf growth, a typical response to foliar applications of 2,4–D, was observed.

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Differences Among Butyl, Ethyl, and Isopropyl Ester Formulations of 2,4–D, 2,4,5–T, and MCPA in the Control of Big Sagebrush[1]

D. N. Hyder, W. R. Furtick, and F. A. Sneva[2]

It has been difficult to accept as conclusive the indications that butyl ester forms of 2,4–D are more effective in the control of big sagebrush *(Artemisia tridentata)* than are isopropyl ester forms (2, 3, 5). Such indications may have been due to the manner of formulating the materials, and to the additives contained, rather than to differences between the esters. Additional information is necessary to prevent bias in the choice among ester forms.

Previous work has shown that the difference between 2,4–D (2,4–dichlorophenoxyacetic acid) and 2,4,5–T (2,4,5–trichlorophenoxyacetic acid) increased in favor of 2,4,5–T as acid rate decreased (6). This indicates the possibility that sufficient control can be obtained with 2,4,5–T at rates below 1 lb/A, and thus justify its choice over 2,4–D when cost considerations are involved.

MCPA has shown promising effectiveness on big sagebrush, and deserved further consideration.

This paper presents data from an experiment designed to obtain information helpful in the choice among ester forms, herbicides, and acid equivalent rates.

Procedure

Butyl, isopropyl, and ethyl ester forms of 2,4–D, 2,4,5–T and MCPA (2–methyl–4–chlorophenoxyacetic acid) were formulated for this experiment in a standardized manner at an acid concentration of 4 lb/gal.[3] They were emulsifiable in water, but contained no wetting additives. The materials were prepared for spraying at acid equivalent rates of 0.5, 1.0, and 1.5 lb/A by emulsifying in water at 6 gal/A with a wetting agent[4] at 0.5 percent by volume.

The treatment selections for the experiment consisted of a 3 x 3 x 3 complete factorial of 3 ester forms, 3 herbicides, and 3 acid rates. A partially confounded incomplete block design was used in which a component of the second order interaction for 2 degrees of freedom was confounded in each replication. The block size was thus 9 plots, and the experiment was replicated 3 times.

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[1]A contribution from Squaw Butte-Harney Experiment Station, Burns, Oregon and Oregon Agricultural Experiment Station, Corvallis, Oregon. Squaw Butte-Harney Experiment Station is jointly operated and financed by the Crops Research Division, A.R.S., U.S.D.A. and Oregon Agricultural Experiment Station. (Formerly jointly operated and financed by the Bureau of Land Management, U.S.D.I. and Oregon Agricultural Experiment Station.) This report is published as Technical Paper No. 1072, Oregon Agricultural Experiment Station.

[2]Range Conservationist, Crops Research Division, A.R.S., U.S.D.A.; Research Assistant, Oregon Agricultural Experiment Station; and Range Conservationist, Crops Research Division, A.R.S., U.S.D.A., respectively.

[3]Experimental compounds used in this study were prepared by the American Chemical Paint Company, Ambler, Pa.

[4]The wetting agent was "Santomerse", Monsanto Chemical Co.

Individual plots were $^1/_{50}$ acre measuring 88 feet long and 9.9 feet wide. All live sagebrush, on an area 80 feet long and 8 feet wide centered within each plot, were counted prior to spraying and again one year after spraying. Percentage-kill data were subjected to analysis of variance.

Spraying was accomplished with a compressed-air sprayer at 35 psi employing a single 8001 nozzle which was moved to obtain a uniform broadcast of solution. Replication I was sprayed on May 1, 1956, replication II was sprayed on May 9, 1956, and replication III was sprayed on May 14, 1956. This timing was in the period of vegetative development when sagebrush susceptibility to the herbicides began in previous years (4, 5, 6). On May 1 sandberg bluegrass *(Poa secunda)* was in the boot stage of development, on May 9 was heading, and on May 14 was fully headed. Such timing gave some opportunity to consider differences in effectiveness between 2,4–D and 2,4,5–T in the period when 2,4,5–T has shown its greatest advantage (6).

The data were analyzed by standard analysis of variance techniques, and treatment means were adjusted for block effects as described by Cochran and Cox (1).

RESULTS AND DISCUSSION

Differences were found among the main effects for ester form, herbicide, and acid rate as evident by the corresponding significant mean squares; however, all interaction mean squares were nonsignificant and small. In previous experiments the primary sources of significant interactions were those involving dates of spraying (4, 6). Since replications in the present experiment involved date differences, an interaction component resulting from the interaction of dates by treatments is likely present in experimental error. Thus, tests of significance for main effects and interactions are perhaps conservative.

Mean kills by ester forms were 46, 53, and 53 percent respectively for isopropyl, butyl, and ethyl esters (Table 1). Butyl and ethyl esters were equally effective, but the isopropyl esters gave kills which were significantly less at a probability level of 1 percent. In the absence of herbicide by ester interaction it is logically assumed that the ester differences were quite uniform with all 3 herbicides; however, it may be observed from the data that the differences among esters were greatest with 2,4–D and least with MCPA. The difference due to ester forms appeared to increase with each successive date of application (Table 2). These data lead one to suspect that the ester differences did not involve MCPA in this experiment, but were concentrated with 2,4–D and 2,4,5–T. On May 14 (a satisfactory timing in practical applications) the isopropyl esters of 2,4–D and 2,4,5–T averaged 11 percent less effective than the mean of the butyl and ethyl esters of these herbicides. However, the deficiency of the isopropyl esters was less apparent at the higher acid rates, which must be used to obtain satisfactory sagebrush control. The practical importance of the difference among ester forms is thus minor, and

Table 1. Big sagebrush mortality following applications of 3 herbicides in 3 ester forms at 3 acid equivalent rates.

Herbicide	Acid rate lb/A	Mortality percentages using various ester forms			
		Butyl	Isopropyl	Ethyl	Average
2,4-D	0.5	37[a]	11	42	30[a]
2,4-D	1.0	46	53	49	49
2,4-D	1.5	72	59	60	64
2,4,5-T	0.5	61	51	53	55
2,4,5-T	1.0	79	66	75	73
2,4,5-T	1.5	86	84	87	86
MCPA	0.5	17	21	26	21
MCPA	1.0	42	33	37	37
MCPA	1.5	33	39	49	40
2,4-D	Average	52[a]	41	50	48[b]
2,4,5-T	Average	75	67	72	71
MCPA	Average	31	31	37	33
Average	0.5	38[a]	28	40	35[b]
Average	1.0	56	50	54	53
Average	1.5	64	60	65	63
Average	Average	53[b]	46	53	51

[a]Interactions were not significant.
[b]LSD at 1 pct. level is 7 percent.

mixtures of the various ester forms as prepared by some chemical companies presumably would have essentially the same effectiveness as straight butyl or ethyl forms.

Replications, which involved a weekly time interval in spraying, were found to be different. Mean kills were 41, 49, and 63 percent respectively on May 1, May 9, and May 14 (Table 2). These data support a previous conclusion that the onset of susceptibility in big sagebrush coincides with the observation of heading on sandberg

Table 2. Big sagebrush mortality following applications of 3 herbicides in 3 ester forms on 3 dates.

Herbicide	Ester form	Mortality percentages on three dates of spraying in 1956			
		May 1	May 9	May 14	Average
2,4-D	Butyl	32	53	70	52
2,4-D	Isopropyl	30	43	50	41
2,4-D	Ethyl	42	48	61	50
2,4,5-T	Butyl	60	75	91	75
2,4,5-T	Isopropyl	59	63	79	67
2,4,5-T	Ethyl	63	73	80	72
MCPA	Butyl	23	24	45	31
MCPA	Isopropyl	28	23	42	31
MCPA	Ethyl	28	38	46	37
2,4-D	Average	35	48	60	48[a]
2,4,5-T	Average	61	70	83	71
MCPA	Average	26	28	44	33
Average	Butyl	38	51	69	53[a]
Average	Isopropyl	39	43	57	46
Average	Ethyl	45	53	62	53
Average	Average	41[a]	49	63	51

[a]LSD at the 5 pct. level is 5 percent.

bluegrass (6). Nearly full susceptibiilty had apparently developed by May 14 when 2,4–D at 1.5 lb/A and 2,4,5–T at 1.0 lb/A killed 78 and 87 percent of the sagebrush respectively (Table 3).

Mean kills by herbicides were 33, 48, and 71 percent respectively for MCPA, 2,4–D, and 2,4,5–T. The superiority of 2,4,5–T was evident throughout the data, and one may note that 0.5 lb/A of 2,4,5–T was more effective than 1.0 lb/A of 2,4–D under the conditions of this experiment.

Table 3. Big sagebrush mortality following applications of 2,4-D and 2,4,5-T at 3 acid equivalent rates on 3 dates.

Herbicide	Acid rate lb/A	Mortality percentages on three dates of spraying in 1956			
		May 1	May 9	May 14	Average
2,4-D	0.5	13	34	43	30
2,4-D	1.0	37	51	59	49
2,4-D	1.5	54	59	78	64
2,4,5-T	0.5	43	52	70	55
2,4,5-T	1.0	63	70	87	73
2,4,5-T	1.5	76	89	93	86
2,4-D	Average	35	48	60	48[a]
2,4,5-T	Average	61	70	83	71
Average	Average	48[a]	59	72	60

[a]LSD at the 5 pct. level is 5 percent.

CONCLUSIONS

Isopropyl ester forms of 2,4–D and 2,4,5–T were less effective on big sagebrush than were butyl or ethyl ester forms. However, the deficiency of the isopropyl esters was less apparent at acid rates high enough to obtain satisfactory sagebrush control. Butyl and ethyl forms might be used with slightly greater confidence, but were not clearly superior to isopropyl forms at practical rates of acid.

The indications are that esters of 2,4,5–T at 1.0 lb/A, or of 2,4–D at 1.5 lb/A, will give kills in excess of 75 percent if applied after sandberg bluegrass is fully headed.

MCPA is not sufficiently effective to compete with the other two herbicides.

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The Aerial Application of 2,4–D to Halogeton[1]

W. C. Robocker, Richard Holland, R. H. Haas, and Kenneth Messenger[2]

Probably no range weed has received such immediate and widespread attention as halogeton *(Halogeton glomeratus* (M. Bieb.) C. A. Mey.) following the large losses of sheep caused by this plant in 1949. Halogeton was first identified in the United States from a specimen collected south of Wells, Nevada, in 1934 (5). Its poisonous properties were discovered in 1942 (7). The time and method of its introduction into the United States are unknown. It is known to be a native of the arid and semiarid plateau regions east of the Caspian Sea and to extend into northwestern China and southwestern Siberia and southward as far as the highlands of Afghanistan and northwestern India.

At the present time, halogeton infests, in varying degrees, an estimated 11 million acres in the States of Nevada, Utah, Idaho, Montana, Wyoming, Colorado, California, and Oregon. The area of infestation appears to be increasing.

The broken terrain and large areas of desert rangelands covered by halogeton were early found to make chemical control of the weed by spraying with ground-operated equipment difficult or impossible. Feasibility of using airplane application of herbicides at volumes as low as 3 gpa were investigated by Burge and O'Hara (3) in 1951. A preliminary trial using aerial application was also made by the Bureau of Land Management, U. S. Department of the Interior, in 1955. The results of that trial were inconclusive but indicated the desirability of conducting such an experiment involving aerial spraying of 2,4–dichlorophenoxyacetic acid (2,4–D) on a sound experimental basis. An interagency project to carry out this research was planned in 1956 with the Bureau of Land Management, and the Plant Pest Control and Field Crops Research Branches of the Agricultural Research Service, U. S. Department of Agriculture, cooperating.

Results obtained over a number of years by various investigators in the Great Basin States (1, 2, 3, 4, 6, 8) indicated that a low volatile ester of 2,4–D applied pre-bloom to halogeton at 2 lb/A, a.e., has given the most satisfactory and economical kill. With the onset of flowering and seed development, halogeton has been found to rapidly develop resistance to injury by 2,4–D. Recommendations for

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[1]Cooperative investigations of the Crops Research Division and Plant Pest Control Division, ARS, USDA; the Bureau of Land Management, USDI; and the Nevada Agricultural Experiment Station.

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ground equipment applications were summarized in 1955 (9) by a committee of interested state and federal agencies and made available in a processed publication for use of control and supervisory personnel engaged in chemical control work.

METHODS AND MATERIALS

The area selected for the airplane spraying trials was in a seeding of crested wheatgrass *(Agropyron cristatum)*, known as the Hubbard Reseeding, north of Wells, Nevada. The area was sown in November, 1952, by the Bureau of Land Management following plowing of the native sagebrush in late spring of 1952. A satisfactory stand of crested wheatgrass existed in the experimental area at the time of the experiments being reported. The halogeton also was quite uniformly distributed, with a density which definitely placed a high majority of plants under extreme inter- and intra-specific competition for soil moisture.

The principal trial was set up as a split-plot design with three replications. The chemical selected was the propylene glycol butyl ether ester of 2,4–D. Rates of application were 1 and 2 lb/A, a.e.; carriers were diesel oil, summer oil-water emulsion (ratio of 1:9), and water; volumes were at 3, 5 and 7 gpa.

A second trial of three replications using a summer oil-water carrier at 5 gpa, 2 lb/A, a.e., of the same ester of 2,4–D was set up adjacent to the larger experiment to compare single vs. double coverage. The double coverage was achieved by two applications of 2½ gpa each, applied from opposite directions over the plots. These were then compared with the equivalent single coverage plots of the larger experiment.

Plots on the main trial were 140 x 1250 feet (4 acres) and those on the double coverage plots were 244 x 1250 feet (7 acres). The plots were sampled by using three 100-foot, permanent transects, read at each foot with a 2-inch loop for presence or absence of live halogeton. The transects were laid out at right angles to the flight direction, one approximately 250 feet from each end of the plot and the third about midway between. Positions of the transects were marked with nails for the final reading. The average of the three samples constituted the plot reading for the split-plot experiment. In the single versus double coverage trial, one transect constituted a sample, with three samples per plot.

First readings of the transects were made at the time of application of 2,4–D on June 19–22, 1956, and a final stand count was made over the same transects on September 17–18, 1956. Effectiveness of the treatments was expressed as a percentage kill by comparison of the first and last readings.

RESULTS AND DISCUSSION

The results of the carriers-volumes-rates study are shown in Table 1. There were no significant differences in effectiveness among the carriers; however, diesel oil and summer oil-water emulsion resulted in greater mean kills. The results also indicated that the higher the

Table 1. Percentage kill of halogeton by volumes, rates and carriers in aerial spraying with 2,4-D at Wells, Nevada, 1956.

Carrier	Volume (gpa)						Average of rates[a]		Average of carriers[a]
	3		5		7				
	1 lb/A	2 lb/A	1 lb/A	2 lb/A	1 lb/A	2 lb/A	1 lb/A	2 lb/A	
	%	%	%	%	%	%	%	%	%
Diesel oil	57.7	87.3	70.9	80.3	81.9	85.9	70.2	84.5	77.3
Summer oil-water	69.6	71.3	76.0	90.0	61.2	91.2	68.9	84.2	76.6
Water	54.6	74.1	55.4	88.2	70.5	79.7	60.2	80.6	70.4
Average	60.6	77.6	67.4	86.2	71.2	85.6	66.4	83.1	74.8
Average of volumes[a]	69.1		76.8		78.4		—	—	

[a]LSD 5 pct. level
Carriers—N. S.
Volumes—N. S.
LSD 1 pct. level
Rates—10.4

volume, the greater the percentage kill. The 2 lb/A rate of 2,4–D was found to be better than the 1 lb/A rate by a highly significant degree. No differences were found in the interactions. In the single versus double coverage trial, the average percentage kill for single coverage was 90.0 per cent and that for double coverage was 80.0 per cent. The difference was highly significant, but no satisfactory explanation for the difference has been found. Coefficients of variability were 17.7 per cent for the split plot and 5.9 per cent for the single versus double coverage trials.

Effects of the spraying on halogeton no doubt were confounded with drought, since little or no rainfall followed application of the herbicide, and plants in untreated areas were severely stunted and showed other typical symptoms of moisture stress. Halogeton plants which were not completely killed generally produced seed, the type (i.e., "black" or "brown") and the amount depending on the degree and nature of injury. The crested wheatgrass did not appear to be adversely affected. Observations on the scattered perennial shrubs indicated general injury as a result of the operation, but the amount could not be ascertained in so short a time after application of the 2,4–D.

The results of this experiment indicate that halogeton kills of 80 percent or better can be obtained from the aerial application of 2,4–D at the rate of 2 lbs/A in 5 to 7 gpa of diesel oil or summer oil-water emulsion. Although this level of control is considered adequate for annual weeds under many cropland conditions, it cannot be considered adequate for halogeton control under rangeland conditions because: (1) the plant is a prolific seed producer and reinfestation occurs when only a few plants survive, (2) the relatively short period of 2,4–D susceptibility does not allow sufficient time for successful retreatment of extensive areas, and (3) the value of much of the land now infested by halogeton is so low that the extensive retreatment necessary to minimize the infestation is not economically feasible. Other factors, such as the lack of specificity to range

forage plants other than grasses, retreatment necessary to control late germinating halogeton plants, and reinfestation by dormant "brown" seeds render the extensive use of 2,4–D for halogeton control a questionable operation.

Feasibility of airplane spraying to reduce first year competition of halogeton with new seedings in order to aid establishment of desirable grasses or other forage species has not been demonstrated. This possibility is now under investigation by the University of Nevada.

SUMMARY AND CONCLUSIONS

In a study of rates of the propylene glycol butyl ether ester of 2,4–D, carriers, and volumes of application appropriate for aerial spraying of halogeton, there was found to be no significant difference among volumes of 3, 5 and 7 gpa, and among diesel oil, summer oil-water emulsion, and water as carriers. There was a highly significant difference in favor of 2 lb/A, a.e., of 2,4–D when compared with a 1 lb/A rate.

A single application of 5 gpa, 2 lb/A, a.e., of 2,4–D was found to be better than two applications of 2½ gpa each by a highly significant degree.

Feasibility of using airplanes for application of 2,4–D to control halogeton on rangelands was not demonstrated.

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An Evaluation of Several Chemicals for Weed Control in Easter Lilies

W. A. Gentner, W. C. Shaw,[1] and F. F. Smith[2]

The gross annual wholesale value of Easter lilies and other ornamental bulb crops grown in the United States in 1950 was estimated at 9.2 million dollars. Because of the high per-acre value of these crops, intensive management is practiced in an effort to produce maximum yields of high quality flowers and bulbs at minimum costs.

The annual cost of controlling weeds in Easter lilies by cultivation and hand hoeing varies from approximately 80 to 400 dollars per acre. In addition, weeds compete for nutrients, water, and light and lower the quality of flowers and bulbs. It is difficult to remove weeds from Easter lilies and other bulb crops by hoeing and cultivation without damaging the crop.

Small grain straw is used in many areas as a mulching material to aid in controlling weeds and to minimize heaving and winter injury. Volunteer small grain originating from the straw mulch often creates a serious weed problem.

The purposes of the studies reported herein were: (1) to evaluate several chemicals as pre- and post-emergence sprays for the control of naturally occurring weed populations in Easter lilies, (2) to develop chemical weed control practices which would give control of volunteer small grain originating from a straw mulch, and (3) to develop chemical weed control practices that would permit maximum benefit from a mulch and require minimum cultivation for weed control.

Literature Review

In 1953 Peabody (5) reported on the screening of several herbicides for their selective properties when applied to iris, tulips, and daffodils as pre- and post-emergence sprays. He concluded from this study that 3–(*p*–chlorophenyl)–1,1–dimethylurea (monuron), an amine salt of 4,6–dinitro ortho secondary butylphenol (DNBP), isopropyl N–(3–chlorophenyl)carbamate (CIPC), and maleic hydrazide were promising for the control of broadleaved weeds in one or more of the above crops, and that none of these herbicides caused apparent injury to the crop in which they were used. Serious injury to iris was reported from the pre-emergence application of trichloroacetic acid (TCA). Visible evidence of tulip injury was induced through the pre-emergence application of an amine salt of 2–methyl–4–chlorophenoxyacetic acid (MCPA).

Later Peabody (6) reported on the effect of low rates of monuron and 3–(3,4–dichlorophenyl)–1–methylurea (DMU) on the bulb yield of several varieties of tulips, iris, and narcissi. The bulb yield of all

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tulip varieties included in these experiments, with the exception of Golden Harvest, was reduced when treated with monuron. However, the application of this herbicide produced no visual adverse effects on the vigor, growth, flower development, or height of tulips. The plant development and bulb yields of iris and narcissi were not effected. DMU treatments significantly reduced the bulb yield of all varieties of the three crops studied with the exception of L'Innocence Narcissi.

Crossley and Adamson (1) studied the use of several herbicides in tulips, daffodils, and iris. They reported that in general their results paralleled those of Peabody. The use of isopropyl N–phenylcarbamate (IPC) was at this time reported to be outstanding for the control of seedling grasses or volunteer cereals in the ornamental bulbous crops studied.

MATERIALS AND METHODS[3]

An evaluation of several chemicals as pre- and post-emergence sprays for weed control in Easter lilies *(Lilium longiflorum)* was initiated in the spring of 1955 and continued in 1956. The experiments were conducted on a Manor loam soil in Montgomery County, Maryland.

The lilies of the 1955 investigation were set in October 1954 at which time the surface of the soil was heavily mulched with wheat straw. At the end of the 1955 growing season the lilies were dug, segregated into flowering and planting stock, planted in October 1955, and again heavily mulched with wheat straw. This planting was used for the 1956 studies.

The experimental design for all studies was a randomized block, replicated three times. Each plot consisted of two rows of lilies 40 inches apart, 20 feet long, and contained approximately 200 bulbs.

The 1955 studies (Table 1) consisted of the investigation of five herbicides applied as pre-emergence sprays: an alkanolamine salt of 4,6–dinitro ortho secondary butylphenol (DNBP, alkanolamine salt), isopropyl N–(3–chlorophenyl)carbamate (CIPC), 3–(*p*–chlorophenyl)–1,1–dimethylurea (monuron), sodium salt of 2,2–dichloropropionic acid (dalapon, sodium salt), and sodium 2,4–dichlorophenoxyethyl sulfate (sesone). These chemicals were applied March 15 and data were taken May 15, 61 days after treatment.

The 1956 studies included the study of seven herbicides applied as pre-emergence sprays (Table 2) and four herbicides applied as directed and broadcast post-emergence sprays (Table 3).

Herbicides included in the 1956 pre-emergence studies were: 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron), 1–*n*–butyl–3–(3,4–dichlorophenyl)–1–methylurea (neburon), an alkanolamine salt of

[3]The authors wish to acknowledge the cooperation of the following Chemical Companies who supplied experimental compounds for these studies: Carbide and Carbon Chemical Company, Chipman Chemical Company, Dow Chemical Company, E. I. duPont deNemours Chemical Company, Heyden Chemical Company, and the Niagara Chemical Division of the Food Machinery and Chemical Corporation.

Table 1. Pre-emergence weed control in lilies, 1955.

Chemical[a]	Rate lb/A	Lily injury scale rating[b]	Percentage control	
			Weedy grasses[c]	Broadleaved weeds
DNBP, alkanolamine salt	8	0.0	57	0
CIPC	6	0.0	90	10
Monuron	2	0.0	90	73
Dalapon, sodium salt	6	0.0	100	27
Sesone	4	0.0	50	10
Check	–	0.0	0	0
Check	–	0.0	0	0

[a]Chemicals were applied on Mar. 15, 1955 and data were taken May 15, 1955.
[b]Injury scale: 0—no effect; 10—complete kill.
[c]Approximately 90 percent of the weedy grass population consisted of volunteer wheat which originated from the straw mulch.

Table 2. Pre-emergence weed control in lilies, 1956.

Chemical[a]	Rate lb/A	Lily injury scale rating[b]	Mean wt. per parent bulb—grams	Stem bulblets per parent bulb	Mean wt. per stem bulblet—grams	Percentage control	
						Weedy grasses[c]	Broad-leaved weeds
Diuron	1	0.0	37.8	1.3	1.8	57	80
	2	0.0	35.6	1.8	1.9	57	77
Neburon	2	0.0	40.2	2.1	2.0	27	63
	4	0.0	39.0	1.7	1.6	67	73
DNBP, alkanolamine salt	8	0.0	40.4	1.2	1.8	53	73
	12	0.0	39.9	2.3	1.7	70	70
CIPC	8	0.0	39.2	1.8	2.2	100	50
	16	0.0	44.5	1.7	2.0	100	70
Dalapon, sodium salt	8	0.0	44.8	1.9	2.3	97	47
	16	0.0	32.6	1.7	1.8	100	57
2,3,6-TBA, sodium salt	1	0.0	40.3	1.9	1.8	73	70
	2	0.0	39.1	2.4	1.9	83	83
2, 4-D alkanolamine salt	2	0.0	34.0	1.7	2.0	63	57
	4	0.0	41.2	2.7	2.0	73	53
Check	—	0.0	36.6	1.5	1.9	0	0
Check	—	0.0	38.9	1.6	1.9	0	0

[a]Chemicals applied 3/27/56; weed control data taken 5/27/56; bulbs harvested 9/22/56.
[b]Injury scale: 0—no effect; 10—complete kill.
[c]Approximately 90 percent of the weedy grass population consisted of volunteer wheat which originated from the straw mulch.

Table 3. Response of Easter lilies to several chemicals applied as post-emergence sprays, 1956.

Chemical[a]	Rate—lb/A	Injury scale rating	
		Broadcast application[b]	Directed application
2,4-D, alkanolamine salt	1/4	8.0	2.0
Sesone	4	0.0	0.0
CIPC	6	5.0	2.0
Neburon	4	2.0	2.0
Check	–	0.0	0.0

[a]Chemicals were applied on June 8, 1956 and data were taken June 22, 1956.
[b]Injury scale: 0—no effect; 10—complete kill.

DNBP, CIPC, the sodium salt of dalapon, the sodium salt of 2,3,6–trichlorobenzoic acid (2,3,6–TBA, sodium salt), and an alkanolamine salt of 2,4–dichlorophenoxyacetic acid (2,4–D, alkanolamine salt). The application date for the above chemicals was March 27 and response data were recorded May 27, 61 days after treatment.

Plots used in the 1956 post-emergence studies were treated with 8 pounds per acre of the sodium salt of dalapon applied as a pre-emergence spray on May 27. These plots were essentially devoid of weedy grasses and broadleaved weeds at the time of the post-emergence treatments. Only the responses of Easter lilies to the herbicides were recorded in these studies.

Chemicals used in the 1956 post-emergence studies were: an alkanolamine salt of 2,4–D, sesone, CIPC, and neburon. These chemicals were applied June 8 as both directed and broadcast sprays and data were taken on June 22. Directed sprays were applied so as to completely cover the soil surface between the rows, allowing the lower 4 inches of the Easter lilies to be sprayed. At the time of treatment lilies were 16 inches tall and the flower buds were 1 inch long. All chemicals were formulated in water containing 1 percent by volume (final concentration) of polyoxyethylene sorbitan monolaurate.[4] They were applied with an experimental plot sprayer (7) operated at 2 mph, 30 psi, and delivering 40 gallons of solution per acre with the exception of the directed post-emergence treatments. These were applied at the same pressure and volume with a knap-sack sprayer.

All rates of application are given on an acid equivalent basis when applicable, and when not applicable, the rates of application are stated on an active ingredient basis.

Injury to lilies was recorded using the following numerical rating scale: 0—no visible effect; 1, 2, 3—slight injury, plants usually recovered with little or no reduction in top growth; 4, 5, 6—moderate injury, plants usually recovered but with reduced top growth; 7, 8, 9—severe injury, plants usually did not recover; 10—all plants killed.

The percentage weed control was obtained by a visual estimate of the reduction of (1) weedy grasses, and (2) broadleaved weeds in the treated plots as compared to the weed population of unsprayed check plots.

All visual ratings presented in Tables 1, 2, and 3, whether on injury to lilies or reduction of weeds, represent the average of two independent ratings.

The weedy grasses consisted largely of volunteer wheat originating from the wheat straw mulch. Broadleaved weeds commonly found in the experimental area were lambsquarters *(Chenopodium album)*, pigweed *(Amaranthus retroflexus)*, oxalis *(Oxalis* spp.), ragweed *(Ambrosia artemisiifolia)*, smartweed *(Polygonum pensylvanicum)*, dandelion *(Taraxacum officinale)*, plantain *(Plantago lanceolata)*, and white clover *(Trifolium repens)*.

Bulb yield data were determined for the 1956 pre-emergence treatments 6 months after chemicals were applied (Table 2). Data were

[4]Supplied as Tween 20 by the Atlas Powder Company.

obtained by digging 6 feet of row from the center of each plot and counting and weighing bulbs and bulblets.

RESULTS AND DISCUSSION

The responses of Easter lilies and weeds to nine herbicides applied as pre-emergence sprays and the response of lilies to four herbicides applied as post-emergence sprays are indicated in Tables 1, 2, and 3.

The results of the 1955 studies indicate that application of the sodium salt of dalapon, monuron, and CIPC gave good grass control. Monuron, in addition to controlling weedy grasses, gave a high degree of broadleaved weed control.

In 1956, applications were made to both flowering and planting stock. Data presented herein are from the flowering stock treatments

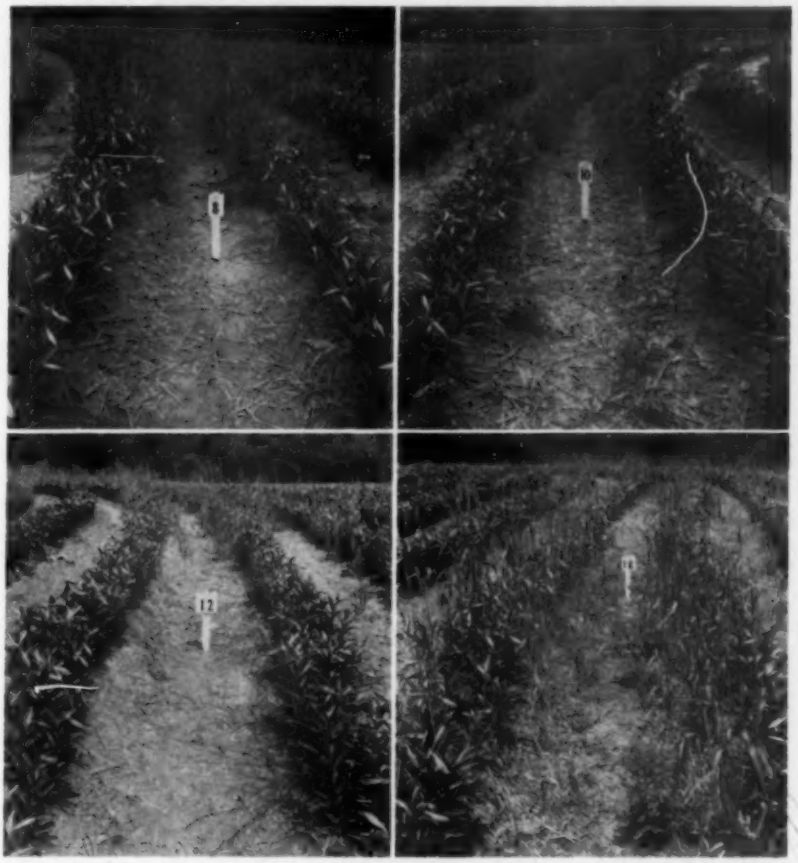

Figure 1. The response of Easter lilies and weeds to several chemicals applied as pre-emergence sprays. Top row, foreground: Left—CIPC 16 lb/A; Right—dalapon 16 lb/A. Background, unsprayed checks. Bottom row, foreground: Left—2,3,6-TBA 2 lb/A; Right—unsprayed check.

only since the responses of planting stock were similar to those from the flowering stock treatments.

The results of the 1956 pre-emergence studies indicate that the sodium salt of 2,3,6–TBA resulted in good control of both weedy grasses and broadleaved weeds. The sodium salt of dalapon, the sodium salt of 2,3,6–TBA, and CIPC gave good control of weedy grasses (Figure 1). Broadleaved weeds were effectively controlled by diuron, the sodium salt of 2,3,6–TBA, and an alkanolamine salt of DNBP.

The degree of broadleaved weed control obtained with the alkanolamine salt of DNBP differed considerably in 1955 and 1956 but the weedy grass control was uniformly good both years.

In the 1955 studies the broadleaved weeds did not germinate until late in the season and the residual activity of DNBP was not adequate to give satisfactory control. The effects of even minor climatic variations, especially temperature, on the activity of the dinitro herbicides have been demonstrated by several investigators (2, 3, 4, 8).

Bulb yield data for the 1956 pre-emergence studies were subjected to an analysis of variance. No significant differences in bulb yield due to treatment were found. None of the chemicals reduced bulb yields.

In the 1956 post-emergence studies CIPC, neburon, and an alkanolamine salt of 2,4–D resulted in injury to the foliage and/or flowers of Easter lilies. In general the directed post-emergence application of the above herbicides caused less damage to vegetative and floral parts than did the broadcast application. Neburon and CIPC applied as a directed or broadcast spray caused a mottling of the foliage. The 2,4–D treatments resulted in damage to both foliar and floral parts (Figure 2). CIPC broadcast treatments inhibited the development of floral parts and caused discoloration and soft rot in the stamens and pistil. No apparent injury to Easter lilies resulted from the sesone post-emergence treatments.

SUMMARY

These preliminary field studies included an evaluation of the selective properties of nine herbicides applied as pre-emergence sprays for the control of weeds in Easter lilies, and the response of Easter lilies to four herbicides applied as directed and broadcast post-emergence sprays. The results reported herein may be summarized as follows:

Pre-emergence results

1. Weedy grasses and broadleaved weeds were satisfactorily controlled for 60 days or more by a single application of 3–(*p*–chlorophenyl)–1,1–dimethylurea (monuron), 3–(3,4–dichlorophenyl)–1,1–dimethylurea (diuron), the sodium salt of 2,3,6–tricholorbenzoic acid (2,3,6–TBA, sodium salt), isopropyl N–(3–chlorophenyl)carbamate (CIPC), sodium salt of 2,2–dichloropropionic acid (dalapon, sodium salt) and an alkanolamine salt of 4,6–dinitro ortho secondary butylphenol (DNBP, alkanolamine salt).

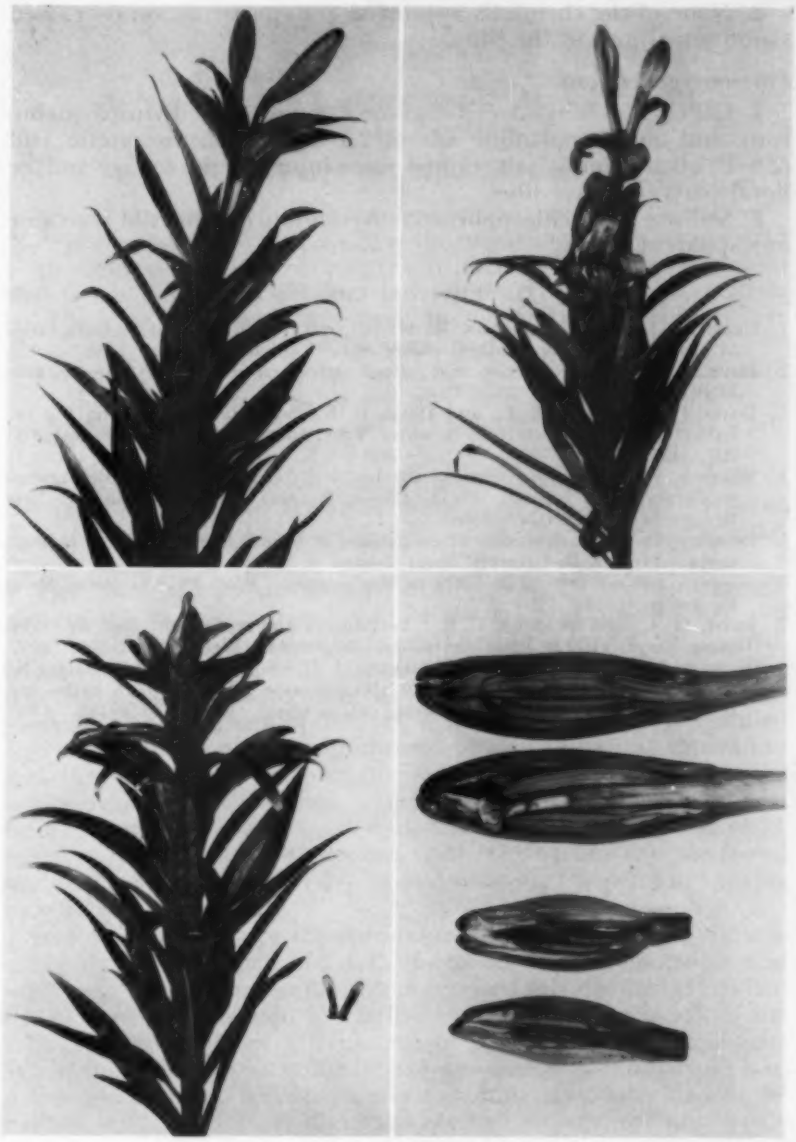

Figure 2. Response of Easter lilies to CIPC and 2,4-D applied as post-emergence broadcast sprays. Top row: Left—check; Right—2,4-D ¼ lb/A. Bottom row: Left—CIPC 16 lb/A; Right upper—two halves of a bud of unsprayed check; and Right lower—two halves of a bud of a treated plant.

2. None of the chemicals applied as pre-emergence sprays caused significant injury to the lilies.

Post-emergence results

1. CIPC, 1–*n*–butyl–3–(3,4–dichlorophenyl)–1–methylurea (neburon), and an alkanolamine salt of 2,4–dichlorophenoxyacetic acid (2,4–D, alkanolamine salt) caused some injury to the foliage and/or floral parts of Easter lilies.

2. Sodium 2,4–dichlorophenoxyethyl sulfate (sesone) did not cause any apparent injury.

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BRIEF PAPERS

A Note on the Chromotropic Acid Reagent for 2,4–D Analysis[1]

V. H. Freed and S. C. Traegde[2]

One of the more common methods of analysis for 2,4–dichlorophenoxyacetic acid (2,4,–D) is the one using chromotropic acid as the color developing reagent (1). In this laboratory it was found that it was difficult to obtain relatively pure chromotropic acid or its disodium salt. As an approach to the preparation of a purer compound, several experiments were tried.

Technical grade chromotropic acid was dissolved in water until the solution was nearly saturated and then acetone was added to precipitate the chromotropic acid. It was found that the nearly white crystals quickly turned a dark gray-green color on drying.

Technical grade disodium salt of chromotropic acid was treated in the same manner, and the same thing occurred; the light colored crystals turned to a dark brown color on drying in the air at room temperature.

The next experiment consisted of dissolving 25 grams of the disodium salt of chromotropic acid in 250 ml of distilled water and heating this until the salt dissolved. The hot solution was filtered, using Whatman No. 1 filter paper, a Buchner funnel, and vacuum. The filtrate was kept hot, and to it was added with stirring a hot solution of 16.8 grams of barium chloride in 100 ml of distilled water. The solution was then allowed to cool to room temperature and the barium salt of chromotropic acid was filtered out of the solution. The salt was then washed with two 50 ml portions of isopropanol and dried at room temperature. This gave a 94% yield, based on the theoretically expected yield. The barium salt was found to discolor only slightly on drying and standing in open air, turning to a light tan color.

In the preparation of the chromotropic acid reagent for the colorimetric determination of 2,4–D, the amount of chromotropic acid used was 2 milligrams per ml of concentrated sulfuric acid (1). When the barium salt was used it was found that it was necessary to use 2.76 milligrams of the salt per ml of concentrated sulfuric acid. When the concentrated sulfuric acid was added to the barium salt, it was found best to add only a small amount of sulfuric acid to the barium salt, immediately shake this well to disperse the salt evenly throughout the sulfuric acid and then add the rest of the sulfuric acid and shake until the barium salt was dissolved. If this procedure was not followed, it was found that lumps of the barium salt formed

[1]Contribution from the Agricultural Chemistry Department, Oregon Agri. Exp. Sta., Corvallis, Oregon.

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which dissolved very slowly in the sulfuric acid, probably due to a coating of barium sulfate forming on the surface of the lumps of the barium salt of chromotropic acid.

Preparation of the barium salt of chromotropic acid has the following advantages, compared to chromotropic acid or the disodium salt:

(a) The barium salt has been found to be more more stable during the drying of the salt, discoloring only slightly during the process, whereas the free acid and the disodium salt were found to discolor badly on exposure to either heat or air.

(b) The barium salt has been found to be more stable during storage than either the free acid or the disodium salt. The barium salt has not been found to appreciably discolor on standing for over 1 year, whereas the free acid and the disodium salt were found to discolor quite badly on being stored for as little as 2 weeks in closed glass bottles.

(c) The sensitivity of the colorimetric determination of 2,4–D has been increased by the use of the barium salt. The slope, calculated as Klett reading per gamma of 2,4–D, when using the free acid or the disodium salt, was found to be 5.2. For the barium salt this value was found to be 5.8. This means that smaller amounts (about 11.5%) of 2,4–D can be detected when using the barium salt.

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News and Notes

An announcement has been received of the Crop Protection and Pest Control Exhibition to be held at the Royal Horticultural Society's New Hall, London, England, May 12 to 15, 1958. Further information can be obtained from John Wheatley, The Crop Protection and Pest Control Exhibition, Leonard Hill House, Eden Street, London, N. W. 1.

Raymond Johnson joined the research staff of the American Chemical Paint Co., Ambler, Pennsylvania, in July 1957, after completing his M.S. degree at the University of Minnesota. He will be concerned with the development of soil sterilants.

James W. Herron was transferred from the Dept. of Entomology and Botany to the Dept. of Horticulture, University of Kentucky, in November 1957. He will continue his research work in control of weeds in horticultural and nursery crops and that of weed identification for the Experiment Station.

John Kirsh has been employed by the American Chemical Paint Co. to work on the development of control methods for woody plants. He recently received his M.S. degree from Pennsylvania State University.

Stanley McLane joined the research staff of the American Chemical Paint Co., in November 1957 where he will be working with the physiology of plant responses to herbicides and other plant growth regulating materials. He was formerly with the Biological Warfare Laboratories, Frederick, Maryland.

The next meeting of the Weed Society of America will be held February 22–25, 1960, at the Cosmopolitan Hotel in Denver, Colorado. The Western Weed Control Conference will act as host conference for this meeting. Officers of the WSA for the next two years are: A. S. Crafts, Univ. of California, president; K. P. Buchholtz, University of Wisconsin, Madison, vice president; and W. C. Shaw, Crops Research Division, ARS, USDA, Beltsville, Maryland, secretary. W. C. Jacob, University of Illinois, Urbana, continues as treasurer and business manager.

The Southern Weed Conference will hold its next meeting in Shreveport, Louisiana, January 21–23, 1959, at the Washington-Youree and Captain Shreve Hotels. Richard Behrens, Crops Research Division, ARS, USDA, College Station, Texas, was elected president; V. S. Searcy, Alabama Agricultural Exp. Station, Auburn, vice president; and W. K. Porter, Jr., Louisiana State University, Baton Rouge, secretary-treasurer for the coming year.

The Northeastern Weed Control Conference elected S. N. Fertig, Cornell University, Ithaca, New York, president; L. G. Utter, Diamond Alkali Co., Painesville, Ohio, vice president; and Donald Schallock, Rutgers University, New Brunswick, New Jersey, secretary-treasurer. The next meeting of the NEWCC will be held January 6, 7 and 8, 1959 at the Hotel New Yorker, New York City.

The next meeting of the North Central Weed Control Conference

is to be held at the Netherlands Hilton Hotel, Cincinnati, Ohio, December 3 and 4, 1958. Officers of the conference for 1958 are Lyle Derscheid, South Dakota State College, Brookings, president; J. R. Foster, Experimental Farm Service, Indian Head, Saskatchewan, Canada, vice president; and D. W. Lambert, State Dept. of Agriculture, State Capitol, Lincoln, Nebraska, secretary-treasurer.

The 3rd Cornell Weed Day is to be held at Cornell University, Ithaca, New York, on July 14, 15 and 16, 1958. This meeting will be in conjunction with the Northeastern sectional meeting of the American Society of Agronomy to be held at Cornell University on the same date.

SUSTAINING MEMBERS

American Chemical Paint Co., Ambler, Pennsylvania
American Smelting & Refining Co., Central Research Laboratories, South Plainfield, New Jersey
Asplundh Tree Expert Company, Jenkintown, Pennsylvania
Association of American Railroads, Chicago, Illinois
Chemical Insecticide Corp., Metuchen, New Jersey
Chipman Chemical Company, Bound Brook, New Jersey
Crag Agricultural Chemicals Division, Union Carbide Chemicals Co., White Plains, New York
Deere and Company, Product Research Dept., Moline, Illinois
Diamond Alkali Company, Cleveland, Ohio
The Dow Chemical Company, Midland, Michigan
E. I. duPont deNemours & Co. Inc., Grasselli Chemicals Dept., Wilmington, Delaware
G. L. F. Soil Building Service, Ithaca, New York
Geigy Agricultural Chemicals, Div. of Geigy Chemical Corp., Yonkers, New York
General Chemical Research Laboratory, Allied Chemical & Dye Corp., Morristown, New Jersey
Hercules Powder Company, Wilmington, Delaware
International Harvester Company, Chicago, Illinois
Miller Chemical & Fertilizer Corp., Baltimore, Maryland
Monsanto Chemical Company, St. Louis, Missouri
National Aluminate Corp., Chicago, Ill.
O. M. Scott & Sons Company, Marysville, Ohio
Reade Manufacturing Company, Inc., Jersey City, New Jersey
Spraying Systems Company, Bellwood, Illinois
Stauffer Chemical Company, New York, New York
Swift and Company (Plant Food Division), Chicago, Illinois
Thompson-Hayward Chemical Company, Kansas City, Missouri
United States Borax and Chemical Corp., Los Angeles, California

BIBLIOGRAPHY OF WEED INVESTIGATIONS
for
July, August, September, 1957

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Crops Research Division

This bibliography of current literature on weeds and their control is issued as a service to those engaged in weed research in the United States and other countries. In issuing this bibliography the Crops Research Division, Agricultural Research Service, U.S.D.A. does not assume responsibility for the subject matter cited.

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Suggestions for Contributors to WEEDS

Manuscripts dealing with all aspects of weed control, regulatory, educational and research, are accepted for publication in WEEDS. Manuscripts should have more than purely local interest. The material described should be more conclusive than progress reports. Articles must be original material previously unpublished elsewhere. Prior publication in brief abstract form is permitted. After review, each manuscript will be accepted for publication upon recommendation of the Editorial Board. The author has the opportunity to make revisions after the review is completed and before publication. Refer to a recent issue of WEEDS to determine details of style to be used.

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Use as short a title as practical. Following the title give the authors name(s). It is desirable to divide the manuscript into sections with headings such as Introduction, Methods and Materials, Results, Discussion, Summary and Literature Cited. Avoid underscoring headings, words or phrases unless you wish them to be printed in italics.

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All chemicals mentioned should be described fully the first time used. Nomenclature, abbreviations and definitions should follow those presented in the Terminology Committee Report, WSA, published in WEEDS 6:77–82, January, 1958.

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